
An Initial Survey of Aquatic Invasive Species Issues in the Gulf of Mexico Region

Established Invasive Species:

Nutria (*Myocastor coypus*)

Giant salvinia (*Salvinia molesta*)



Potential Future Invasive Species:

Zebra mussel (*Dreissena polymorpha*)

Spotted jellyfish (*Phyllorhiza punctata*)

**Invasive Species Focus Team
Gulf of Mexico Program**

Version 4.0



**AN INITIAL SURVEY OF
AQUATIC INVASIVE SPECIES ISSUES
IN THE GULF OF MEXICO REGION**

September 2000

Version 4.0
Released on August 31, 2001

Submitted to:

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EPA/OCPD Contract No. 68-C-00-121
Work Assignment 1-07

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Acknowledgements

The Gulf of Mexico Program and the document authors would like to acknowledge the volunteer efforts of the many individuals that contributed to this report.

Technical direction throughout the development of the document was provided by the Characterization Report Workgroup, an ad-hoc working subcommittee of the Gulf of Mexico Program Invasive Species Focus Team. Workgroup members volunteered an appreciable amount of their time and contributed directly to the report's development. Workgroup members included:

- Marilyn Barrett-O'Leary, Louisiana Sea Grant Program
- Henry Folmar, Mississippi Department of Environmental Quality
- Pam Fuller, U.S. Geological Survey
- Bill Holland, Gulf of Mexico Program
- Herb Kumpf, National Marine Fisheries Service
- Ron Lukens, Gulf States Marine Fisheries Commission
- Dan Roberts, Florida Fish and Wildlife Conservation Commission

Many Gulf-region experts volunteered their time to provide information or review drafts of the document. They included:

- Jimmy Avery, Aquaculture Extension Specialist, MSU
- Paul Carangelo, Coastal Environmental Planner
- David Felder, Mississippi Department of Environmental Quality
- Joe Hendrix, GMP Citizens Advisory Committee Fisheries Representative (Texas)
- Jeffrey Hill, Dept. of Fisheries and Aquatic Sciences, UF
- Dewayne Hollin, Texas Sea Grant Program
- Heidi Lovett, MRAG Americas
- Greg Lutz, Specialist and Professor, Aquaculture, LSU Ag Center
- John MacMillan, President, National Aquaculture Association
- Susan McCarthy, Gulf Coast Seafood Laboratory, U.S. Food and Drug Administration
- Tom McIlwain, National Marine Fisheries Service
- Larry McKinney, Texas Parks & Wildlife Department
- Benedict Posadas, MSU Coastal Research and Extension Center
- Granvil Treece, Texas Sea Grant Program
- Robert Stickney, Texas Sea Grant Program
- Edwin Theriot, U.S. Army Corps of Engineers
- Sherman Wilhelm, Division of Aquaculture, FDACS
- Paul Zajicek, Division of Aquaculture, FDACS

This document is a product of the Invasive Species Focus Team, which guided the report's development, reviewed drafts, and approved the final draft. Focus Team members include:

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- Ron Lukens, Gulf States Marine Fisheries Commission
- Vernon Minton, Alabama Department of Conservation and Natural Resources
- Cynthia Moncreiff, Gulf Coast Research Laboratory
- Dan Roberts, Florida Fish and Wildlife Conservation Commission
- Deborah Schultz, Barataria-Terrebonne National Estuary Program
- Thomas Schultz, Coastal Research and Extension Center, Mississippi State University
- Robert Stender, Chief of Naval Education and Training, U.S. Navy
- Bruce Thompson, Coastal Fisheries Institute, Louisiana State University
- Tom Van Devender, Mississippi Department of Marine Resources

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Zebra mussel – USGS/BRD (permission obtained from Colette Jacono, USGS/BRD, Gainesville, Florida)

Battelle prepared this document for the Gulf of Mexico Program under EPA/OCPD Contract No. 68-C-00-121, Work Assignments WA0-07 and WA1-07. The Principal Investigator was Brent Ache; other Battelle contributors included Debbie Tanis and Angela Walters.

Acronyms

AAPA	American Association of Port Authorities
ADCNR	Alabama Department of Conservation and Natural Resources
AEC	Aquaculture Executive Committee (Texas)
AMS	Agricultural Marketing Service
ANSTF	Aquatic Nuisance Species Task Force
APCS	Aquatic Plant Control Section (Louisiana)
APHIS	Animal and Plant Health Inspection Service
APMS	Aquatic Plant Management Section (Florida)
APPS	Act to Prevent Pollution from Ships (1980)
ARS	Agricultural Research Service
ASPEA	Alien Species Prevention and Enforcement Act of 1992
ATF	Aquaculture Task Force (Mississippi)
BIA	Bureau of Indian Affairs
BIPM	Bureau of Invasive Plant Management (Florida)
BLM	Bureau of Land Management
BMP	Best Management Practice
BOR	Bureau of Reclamation
CEC	North American Commission for Environmental Cooperation
CEQ	Council on Environmental Quality
CSREES	Cooperative State Research, Education, and Extension Service
DEA	Drug Enforcement Agency
DOD	United States Department of Defense
DOE	United States Department of Energy
EEZ	Exclusive Economic Zone
EIS	Environmental Impact Statement
EPPC	Exotic Pest Plant Council
ERS	Economic Research Service
ESA	Endangered Species Act of 1973
FAS	Foreign Agricultural Service
FAWCA	Florida Aquatic Weed Control Act
FDACS	Florida Department of Agriculture and Consumer Services
FDEP	Florida Department of Environmental Protection
FFWCC	Florida Fish and Wildlife Conservation Commission
FHA	Federal Highway Administration
FICMNEW	Federal Interagency Committee for Management of Noxious and Exotic Weeds
FLEPPC	Florida Exotic Pest Plant Council
FNPS	Florida Native Plant Society
FSA	Farm Service Agency
FNAPCA	Florida Nonindigenous Aquatic Plant Control Act
GAO	U.S. General Accounting Office
GIWW	Gulf Intracoastal Waterway
GMP	Gulf of Mexico Program
GSMFC	Gulf States Marine Fisheries Commission
ICES	International Council for Exploration of the Seas

IHHNV	Infectious Hypodermal and Hematopoietic Necrosis Virus
IMO	International Maritime Organization
ISC	Invasive Species Council
ISFT	Invasive Species Focus Team
JSA	Joint Subcommittee on Aquaculture
LDAF	Louisiana Department of Agriculture and Forestry
LDWF	Louisiana Department of Wildlife and Fisheries
LMRCC	Lower Mississippi River Conservation Committee
LWF	Louisiana Wildlife Federation
LWFC	Louisiana Wildlife and Fisheries Commission
MARPOL	International Convention for the Prevention of Pollution from Ships
MDAC	Mississippi Department of Agriculture and Commerce
MDWFP	Mississippi Department of Wildlife, Fish, and Parks
MDMR	Mississippi Department of Marine Resources
MEPC	Marine Environmental Protection Committee (United Nations)
NANPCA	Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990
NBWIC	National Ballast Water Information Clearinghouse
NEPA	National Environmental Policy Act of 1970
NISA	National Invasive Species Act of 1996
NMFS	National Marine Fisheries Service
NMI	Northeast-Midwest Institute
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRC	National Research Council
NRCS	National Resources Conservation Service
NSF	National Science Foundation
OSM	Office of Surface Mining Reclamation and Enforcement
OTA	Office of Technology Assessment
PHS	Public Health Service
SERC	Smithsonian Environmental Research Center
SPF	Specified Pathogen Free
SVW	Shrimp Virus Workgroup
TDA	Texas Department of Agriculture
TMDL	Total Maximum Daily Load
TPWC	Texas Parks and Wildlife Commission
TPWD	Texas Parks and Wildlife Department
TNC	The Nature Conservancy
TNRCC	Texas Natural Resource Conservation Commission
TSV	Taura Syndrome Virus
UMRCC	Upper Mississippi River Conservation Committee
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WBCA	Wild Bird Conservation Act of 1992
WMD	Water Management District
WSSV	White Spot Syndrome Virus
YHV	Yellow Head Virus

Executive Summary

What is the Scope of This Report?

Humans have a long history of deliberately introducing terrestrial and aquatic species to new areas for agriculture, horticulture, soil conservation, sport fishing, hunting, pets, and a host of other reasons. These nonindigenous species are greatly beneficial to society, providing much of the food we eat, sustaining significant sectors of our economy, offering recreational opportunities, and serving as pets in our homes and flora in our gardens. At the same time, human activities like travel, trade, and natural habitat alteration have caused many unplanned or accidental introductions of species to new areas. The contemporary massive transformation of the natural environment and worldwide transport of people and cargo now facilitate species introductions – both deliberate and accidental – at a rate that completely overshadows natural rates of species movement (OTA 1993), and makes large-scale range expansions across mountains and oceans common. For the purposes of this report, we focus on these human-facilitated movements of species – both deliberate and accidental – to new areas: throughout this report such species are referred to as nonindigenous species.

For those nonindigenous species introduced to open ecosystems (i.e., outside of human control and confinement), only a portion will successfully establish one or more permanent, reproducing populations (Mack et al. 2000). These *established* nonindigenous species can be categorized by their impacts – ecologic and economic – in the new ecosystem: beneficial, harmful, unknown, or neutral (although, in many cases, impacts are a mix of beneficial and harmful) (OTA 1993).

Many intentionally established nonindigenous species provide great benefit to agriculture, horticulture, recreational fishing, biological control, etc. However, a small number of established nonindigenous species, including species both intentionally and unintentionally introduced, result in serious threats to the diversity or abundance of native species; the ecological stability of impacted ecosystems; economic activities (e.g., agricultural, aquacultural, commercial, or recreational) dependent on these ecosystems; and human health. The impacts of these few species is considerable; one study estimates that the overall economic impact of harmful nonindigenous species is a loss of more than \$138 billion per year (Pimentel et al. 1999). This report purposefully focuses on the small number of nonindigenous species that are harmful, or potentially harmful (i.e., those with unknown impacts), and does not further discuss beneficial nonindigenous species. Throughout this report, the term *invasive species* is used to denote those nonindigenous species with any form of harmful impact in open ecosystems.

Invasive Species: *A species that threatens the diversity or abundance of native species; the ecological stability of impacted ecosystems; economic activities (e.g., agricultural, aquacultural, commercial, or recreational) dependent on these ecosystems; and human health. Synonyms for invasive species include harmful species, injurious species, invader, noxious species, nuisance species, pest, and weed.*

This report focuses on just those invasive species that are obligated to live in a waterbody for part or all of their lives: aquatic invasive species. Of all aquatic taxa, this initial survey concentrates on fish, non-insect aquatic invertebrates, aquatic mammals, aquatic microbes, and aquatic and semi-aquatic plants; it does not consider aquatic birds or aquatic insects. In order to adequately survey aquatic invasive species issues, including potential future aquatic invasive species issues, in the Gulf of Mexico region, the scope of this report covers:

- Invasive nonindigenous aquatic species (1) established in free-living populations, (2) in a captive or managed state in the Gulf of Mexico region, or (3) not yet introduced to the Gulf of Mexico region, but with an active introduction pathway.
- Indigenous aquatic species aggressively expanding their natural ranges or density in an area due to human activities (e.g., habitat alteration), to the detriment of other native species or ecosystems.
- Uncontrolled and unmonitored introductions of nonindigenous aquatic species, where there is no appropriate assessment of risks.

This report focuses only on the U.S. portion of the Gulf of Mexico ecosystem. The study area for this report includes the area within the political boundaries of the five Gulf States – Florida, Alabama, Mississippi, Louisiana, and Texas – and waters of the Gulf of Mexico to the seaward boundary of the U.S. Exclusive Economic Zone.

What is the Purpose of This Report?

The Gulf of Mexico Program (GMP) Management Committee serves as the Gulf of Mexico Regional Panel (Gulf Panel) to the national Aquatic Nuisance Species Task Force (ANSTF). The Gulf Panel exists to coordinate prevention, research, management, control, and outreach efforts in the Gulf of Mexico region, and is responsible for submitting an annual report to the ANSTF. In addition, the GMP Invasive Species Focus Team (ISFT) has committed to assisting the five Gulf States in developing invasive species management plans. To begin fulfilling these responsibilities in a coordinated manner, the ISFT has developed this report to:

- Compile background and technical information needed to generate the Gulf Panel's first (2000) Annual Report to the ANSTF;
- Begin compiling information that will assist the five Gulf States in developing aquatic components of their invasive species management plan(s);
- Generate a regional information and coordination resource for aquatic invasive species management and research activities, targeting the GMP's broad group of stakeholders.

This report is current as of its completion date, September 2000. However, due to the highly dynamic nature of bioinvasions, new species introductions and management responses continue to occur. The ISFT intends this report to be a “living document,” to be expanded and updated at the discretion of the ISFT.

What Nonindigenous Aquatic Species Occur in the Gulf of Mexico Region?

It is important to understand the magnitude, origins, and pathways of nonindigenous aquatic species introductions to an area, as these introductions form the “pool” of established species from which a few harmful invasive species arise. The Gulf region is vulnerable to aquatic species introductions due to the magnitude and variety of viable pathways created by, for example: (1) large numbers of people, vessels, and airplanes, and large volumes of cargo, coming through multiple large-scale, international ports and airports; (2) year-round, cross-state recreational boating, fishing, and other aquatic recreational activities; (3) numerous industries import, breed, grow-out, and warehouse a large variety of nonindigenous aquatic species; and (4) the Gulf Intracoastal Waterway and Mississippi River, which provide the 5 Gulf states with an aquatic connection to more than half of the 48 states in the continental U.S. The subtropical climate and abundant aquatic habitats make the Gulf of Mexico region naturally hospitable to nonindigenous aquatic species (Devine 1998, Cox 1999).

Several descriptions of the occurrence and status of nonindigenous aquatic species in Florida have been published (McCann et al. 1996, Simberloff et al. 1997, Goodyear 2000), but similar descriptions for other Gulf States and the Gulf of Mexico region as a whole are less frequent. The U.S. Geological Survey (USGS) maintains an Internet-accessible database (<http://nas.er.usgs.gov>) of nonindigenous aquatic species that is searchable by state or by watershed drainage (USGS 2000). To date, nonindigenous freshwater species introductions have received more attention than estuarine and marine species; there are no systematic studies of nonindigenous estuarine and marine invertebrates or plants in Florida waters (Carlton and Ruckelshaus 1997), or for the Gulf region.

An inventory of nonindigenous aquatic species occurrences in the Gulf of Mexico region was prepared for this report. The inventory attempts to identify those nonindigenous species that occur or have occurred in freshwater, estuarine, and marine environments in the Gulf of Mexico region, by Gulf State. This initial iteration of the inventory focuses on aquatic microbes, non-insect aquatic invertebrates, fishes, amphibians, aquatic reptiles, aquatic mammals, algae, aquatic plants, and semi-aquatic plants; it does not address nonindigenous aquatic birds, aquatic insects, or any terrestrial species in the Gulf region. Information for the inventory was gathered via Internet-based and other databases, and Gulf-region experts (the primary information source was the USGS database described above). The complete *Inventory of Nonindigenous Aquatic Species in the Gulf of Mexico Region* is provided in Appendix B, and summarized in Tables ES1, ES2, ES3, and ES4.

Table ES1. Number of Nonindigenous Aquatic Microbes Occurring (or Having Occurred at Least Once) in the Five Gulf States.

State	Shrimp Viruses	Bacteria	Protozoa	Fungi	TOTAL
AL	*	1	2	*	3
FL	1	2	7	*	10
LA	*	*	2	*	2
MS	*	*	2	*	2
TX	3	1	1	*	5

* = None.

Table ES2. Number of Nonindigenous Aquatic Invertebrates (Non-Insect) Occurring in the Five Gulf States.

State	Tuni- cates	Bryo- zoans	Sponges	Coelen- terates	Flat- worms	Round- worms	Seg. Worms	Moll- usks	Crust- aceans	TOTAL
AL	*	*	*	1	*	*	*	3	3	7
FL	3	6	*	2	7	2	2	19	23	64
LA	*	*	*	*	*	*	*	3	5	8
MS	*	*	*	1	*	*	*	2	2	5
TX	1	*	*	*	*	1	*	9	5	16

* = None.

Table ES3. Number of Nonindigenous Aquatic Vertebrates Occurring in the Five Gulf States.

State	Fishes	Amphibians	Reptiles	Mammals	TOTAL
AL	51	*	1	1	53
FL	117	13	18	1	149
LA	27	2	*	1	30
MS	22	*	*	1	23
TX	98	4	3	1	106

* = None.

Table ES4. Number of Nonindigenous Aquatic Plants Occurring in the Five Gulf States.

State	Algae	Aquatic Vascular Plants	Semi-Aq. Vascular Plants	TOTAL
AL	1	25	6	32
FL	2	45	23	70
LA	1	34	10	45
MS	1	25	7	33
TX	2	30	12	41

What Are the Current Aquatic Invasive Species Management Priorities for the Five Gulf States?

Tables ES5 and ES6 present the results of interviews with Gulf State agency representatives on the GMP Invasive Species Focus Team to identify aquatic invasive species that are **current management priorities** or **potential future management priorities** in each of the five Gulf States (see Section 4.0 of the document for detailed interviewed results). In some cases, as noted below, the interviewed state agency representatives sought the input of a larger group of state stakeholders, while in other cases interview results represent the opinions of one agency representative. The interviews were intended to produce a representative, rather than comprehensive, list of Gulf-region management priorities. It has been recommended that a more formal and extensive survey be conducted for any future compilation of this information.

For the purposes of the interviews, “current management priority” is defined as an invasive, or potentially invasive, aquatic species that the state is most concerned with managing at the present time. “Potential future management priority” is defined as an invasive, or potentially invasive, aquatic species that (1) does not yet occur in the state, but that has an active introduction pathway, or (2) already has been introduced to the state, and is of concern due to the magnitude of adverse impacts experienced in similar ecosystems. It is critical to recognize that management priorities can be based on the actual or perceived threat a species poses, even though it does not yet occur in the state. Similarly, invasive or potentially invasive species that already occur in a state may not necessarily be a management priority in that state.

What Management Framework is Available to Address Aquatic Invasive Species Issues?

At the federal level, the current management framework for invasive species has its foundation in over 28 pieces of legislation and is dependent on activities of more than two dozen different federal agencies. In general, there are substantial gaps in federal laws and programs to prevent the introduction of invasive species, and it is clear that significant risks remain unaddressed (ISC 2000).

Existing legislation is targeted toward both controlling particular species and regulating specific vectors. Species-oriented legislation prohibits or regulates introduction of species that have caused problems, or have the potential to cause problems. Much of the current federal and state legislation contains lists of prohibited and restricted species. For prohibited lists, it is usually illegal to import, sell, possess, or transport those species; restricted species can usually be imported, cultured, sold, and/or transported with one or more permits from appropriate natural resource agencies. Agency rules, and associated permits, for restricted species often differentiate between releases to human control and confinement (e.g., aquaculture, ornamental fish farms, research facilities, public aquaria) and releases to open ecosystems.

It has been suggested that many currently implemented vector-based controls are compromised by understaffing and time pressure (Ruesink et al. 1995). For example, for foreign imports, the volume of trade creates a tremendous burden on an understaffed federal inspection system and forces a strong reliance on self-reporting by the shipping industry (OTA 1993). Equally problematic, there has been little support for regulations addressing unintentional “by-product” introductions (Corn et al. 1999). However, recent efforts to manage ballast water discharges represent a serious attempt to understand and control a high-risk introduction vector.

Table ES5. Current and Potential Future Management Priorities in the Five Gulf States, September 2000: Invasive Aquatic and Semi-Aquatic Plant Species.

SCIENTIFIC NAME	COMMON NAME	AL	FL	LA	MS	TX
<i>Alternanthera philoxeroides</i>	alligatorweed		√	√		√
<i>Aureoumbra lagunensis</i>	brown tide algae					√ ^a
<i>Brachiaria mutica</i>	paragrass		√			
<i>Casuarina equisetifolia</i>	Australian pine		√			
<i>Caulerpa toxifolia</i>	tropical green algae		P			
<i>Colocasia esculenta</i>	wild taro		√			
<i>Cylindrospermopsis raciborskii</i>	blue-green algae		P			
<i>Eichhornia crassipes</i>	water hyacinth	√	√	√	√	√
<i>Hydrilla verticillata</i>	hydrilla	√	√	√	√	√
<i>Hygrophila polysperma</i>	Indian swampweed		√			
<i>Hymenachne amplexicaulis</i>	West Indian marshgrass		√			
<i>Imperata cylindrica</i>	cogongrass			P		
<i>Ipomoea aquatica</i>	waterspinach		√			P
<i>Lythrum salicaria</i>	purple loosestrife			P		P
<i>Melaleuca quinquenervia</i>	paperbark (melaleuca)		√			
<i>Mimosa pigra</i>	catclaw mimosa		√			
<i>Panicum repens</i>	torpedograss		√	√		
<i>Pistia stratiotes</i>	waterlettuce		√	√		√
<i>Pueraria montana</i>	kudzu			√		P
<i>Salvinia minima</i>	common salvinia			√		√
<i>Salvinia molesta</i>	giant salvinia	√	√	√	√	√
<i>Sapium sebiferum</i>	Chinese tallow tree			√	√	√
<i>Schinus terebinthifolius</i>	peppertree		√			
<i>Solanum tampicense</i>	wetland nightshade		√			

Source: This information was provided by representatives of Gulf State agencies and organizations on the Gulf of Mexico Program Invasive Species Focus Team. At this time, it is intended to be a representative, rather than comprehensive, list of management priorities.

√ = Current management priority in the state.

P = Potential future management priority for the state.

Note: Designations are not based on occurrence in the state, but rather priorities for management. Some of the unchecked species exist in the state, but are not currently considered priorities for management.

^a = Cryptogenic (a species whose status as indigenous or nonindigenous remains unresolved)

Table ES6. Current and Potential Future Management Priorities in the Five Gulf States, September 2000: Invasive Aquatic Animal Species.

SCIENTIFIC NAME	COMMON NAME	AL	FL	LA	MS	TX
<i>Anguillicola crassus</i>	exotic nematode on American eels					P
<i>Belonesox belizanus</i>	pike killifish		√			
<i>Callinectes bocourti</i>	chocolate brown crab	P				
<i>Carcinus maenus</i>	green crab	P		P		P
<i>Charybdis helleri</i>	marine swimming crab		√	P		P
<i>Cichlasoma cyanoguttatum</i>	Rio Grande cichlid			√		√
<i>Cichlasoma urophthalmus</i>	Mayan cichlid		√			
<i>Cittarium pica</i>	West Indian trochid		√			
<i>Clarias batrachus</i>	walking catfish		√			
<i>Corbicula fluminea</i>	Asian clam	P	√	P		P
<i>Crassostrea gigas</i>	Japanese (or Pacific giant) oyster		P			√
<i>Ctenopharyngodon idella</i>	grass carp	P	P ^a	√		√
<i>Dreissena polymorpha</i>	zebra mussel	√	P	P	√	P
<i>Drymonema dalmatinum</i>	jellyfish	P				
<i>Eriocheir sinensis</i>	Chinese mitten crab	P		P		P
<i>Glossodoris sedna</i>	marine nudibranch		√			
<i>Hypophthalmichthys molitrix</i>	silver carp	P		√		P
<i>Hypophthalmichthys nobilis</i>	bighead carp	√		√		P
<i>Limnoperna fortunei</i>	freshwater mussel		P			
<i>Litopenaeus vannamei</i>	Pacific white (or whiteleg) shrimp		P			
<i>Monopterus albus</i>	swamp eel		√		P	
<i>Mylopharyngodon piceus</i>	black carp			P	P	P
<i>Myocastor coypus</i>	nutria			√	√	√
<i>Mytilopsis leucophaeata</i>	Conrad's (or dark) false mussel		√			
<i>Mytilopsis sallei</i>	Salle's (or Santa Domingo) false mussel		√ ^b			
<i>Neogobius melanostomus</i>	round goby			P	P	
<i>Oreochromis aureus</i>	blue tilapia		P			√
<i>Oreochromis mossambicus</i>	Mozambique tilapia		√			√
<i>Oreochromis niloticus</i>	Nile tilapia				√	
<i>Perna perna</i>	brown (or Mexihalo) mussel			P		P
<i>Perna viridis</i>	green mussel		√			
<i>Phyllorhiza punctata</i>	spotted jellyfish	√		P	√	P
<i>Pinctada margaritifera</i>	black-lipped (or Pacific) pearl oyster		P			
<i>Platychoirograpsus spectabilis</i>	saber crab		√			
<i>Pomacea canalicula</i>	channeled applesnail					√
<i>Rapana venosa</i>	veined rapa whelk		P			
<i>Sarotherodon melanotheron</i>	blackchin tilapia		√			
Taura Syndrome Virus	shrimp virus					√
<i>Tilapia mariae</i>	spotted tilapia		√			
<i>Tridacna spp.</i>	giant clams		P			
White Spot Syndrome Virus	shrimp virus					√

Table ES6, continued. Current and Potential Future Management Priorities in the Five Gulf States, September 2000: Invasive Aquatic Animal Species, cont.

Source: This information was provided by representatives of Gulf State agencies and organizations on the Gulf of Mexico Program Invasive Species Focus Team. At this time, it is intended to be a representative, rather than comprehensive, list of management priorities.

√ = Current management priority in the state.

P = Potential future management priority for the state.

Note: Designations are not based on occurrence in the state, but rather priorities for management. Some of the unchecked species exist in the state, but are not currently considered priorities for management.

^a = Diploid stocks only.

^b = Cryptogenic (a species whose status as indigenous or nonindigenous remains unresolved)

Some researchers contend that a consensus is developing that the invasive species problem has reached proportions demanding a coherent national policy to guide future actions (Williams and Meffe 1999). In 1997, more than 500 scientists and natural resource managers wrote the Clinton Administration to express their deep concern about the damage done by invasive species every year (ISC 2000). This action resulted in the establishment of a national Invasive Species Council (ISC), through Presidential Executive Order, which issued a national invasive species management plan in January 2001. At the same time, the recognition of federal framework limitations has initiated state and regional management and planning (Fletcher 2000).

Universally it is recognized the prevention of new introductions of invasive species, and the immediate eradication of new colonies of invasive species, is the most effective, and cost effective, method to control invasive species (Mack et al. 2000). Risk-based decision-making approaches, based on available information, can help managers to quantitatively evaluate the likelihood of an undesired event and the likelihood of harm or damage being caused (Hayes 1998). At this time though risk-based decision criteria are currently absent from most U.S. policy for intentional introductions, although the ANSTF recently presented a generic nonindigenous aquatic organisms risk analysis review process (ANSTF 1996). Some researchers and managers advocate the implementation of zero-risk policies at national and international levels (Mack et al. 2000), assumably for species introductions to open ecosystems versus imports to human control and confinement (e.g., aquaculture).

Given the magnitude of active introduction pathways and the diversity of nonindigenous species and receiving ecosystems, an adaptive management approach will have to be adopted. This way the relative ecological, economic, and human health threats posed by invasive species will periodically re-prioritize prevention, management, control, and public education efforts to yield the most benefit for the environment, economic vitality, and human health. In addition, management of invasive species ultimately must be a global endeavor. Efforts to restrict invasive species introductions to the U.S. will be aided through coordination with the countries-of-origin for these species (ISC 2000).

All five Gulf States have statutory provisions applicable to nonindigenous species introductions, and specific provisions applicable to at least selected aquatic species (specific Gulf State statutes and regulations are described in Sections 7.5 through 7.9). Each Gulf State

maintains prohibited and/or restricted species lists, and conducts permit programs to regulate the import, possession, sale, and transport of selected species.

To date, none of the five Gulf States has established a comprehensive invasive species management plan, although plans for a few plant species have been developed in Florida (FEPPC 1997, FEPPC 1999). However, planning efforts are beginning at both the state and regional levels (Texas Sea Grant Program 1998). In the summer of 2000, the Louisiana Sea Grant Program sponsored the state's first meeting to discuss development of an invasive species management plan (Barrett O'Leary, pers. comm.). Likewise, Florida Governor Jeb Bush recently requested that the Florida Department of Environmental Protection facilitate a meeting of Florida's state agencies to determine the most effective way to develop a comprehensive invasive species management plan (Bush 2000).

Two primary statutes and a noxious weed program in Florida, Texas's Statewide Vegetation Management Plan, and Alabama's Nonindigenous Aquatic Plant Control Act, appear to adequately address invasive plants in those states. In fact, the Florida and Texas statutes and programs could serve as good models for state invasive species management plans, as they provide a lead executing agency, scientific research directives, prohibitions on introductions, and grant programs for local agencies (Fletcher 2000). However, in both of these cases, the states do not have provisions applicable to freshwater and saltwater animals: statutory authorities would have to be expanded for truly comprehensive planning. In Texas and Louisiana nonindigenous animal restrictions are basically a patchwork of aquaculture and wildlife provisions (Fletcher 2000).

With respect to regional planning, Fletcher (2000) indicates that no Gulf State statutes provide (1) provisions to offer notice of identifications, introductions, or infestations to neighboring states or (2) any provisions for mitigation. Without such provisions, significant conflict can occur among states when a nonindigenous species introduction is intentional and controversial (Fletcher 2000).

What Research Resources are Available and What Research is Still Needed?

An inventory of recent peer-reviewed scientific research relevant to selected Gulf-region aquatic invasive species issues was prepared for this report. The purpose of the inventory is to (1) serve as an initial regional scientific directory on key current and emerging invasive species issues and (2) begin identifying regional research gaps and needs. This iteration of the Research Inventory, found in Appendix I, contains over 400 individual references and contains references on over 37 key species.

Research Needs

Initial lists of Gulf-region invasive species research needs prepared by various committees of the GMP are presented in Section 10.0. The GMP is currently sponsoring meetings of an ad-hoc Experts Panel for Invasive Species Research. The Panel Co-Chairs are Dr. Herb Kumpf, National Marine Fisheries Service, and Dr. Karen Steidinger, Florida Marine Research Institute.

It is expected that the Expert Panel will complete a thorough invasive species research guidance/research needs report in 2001.

Gulfwide Aquatic Invasive Species Issues Addressed by the GMP Invasive Species Focus Team: Shrimp Viruses and Ballast Water

To facilitate Gulf-wide communication and coordination on invasive species issues, the GMP sponsors a multi-stakeholder Invasive Species Focus Team (ISFT). While the ISFT serves as a venue for all regional, state, and local invasive species problems, it is currently focused on three issues of Gulfwide importance: shrimp viruses, ballast water as an introduction pathway, and the prevention of new introductions of invasive species. To date, the majority of the Focus Team's efforts have been concentrated on the first two issues.

Shrimp Viruses

Of the 14 penaeid shrimp viruses known worldwide, three exotic viruses have been identified in the Gulf of Mexico region: White Spot Syndrome Virus (WSSV), Taura Syndrome Virus (TSV), and Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV). Another exotic shrimp virus, Yellow Head Virus (YHV), usually co-occurs with WSSV (Lightner 1996a, Lightner 1996b), but has not been identified in live shrimp in the Gulf of Mexico region (McIlwain, pers. comm.). WSSV is endemic throughout much of Asia, and TSV and IHHNV are endemic in wild shrimp populations throughout much of Central and South America (JSA 1997). It has been shown that all three viruses are carried by some live shrimp, but they also have been found in imported frozen shrimp, shrimp by-products, and in a number of non-penaeid shrimp and other crustacean species (e.g., copepods, crabs, and crayfish) (Lightner 1996a, Lightner 1996b, JSA 1997). Note that none of these three exotic shrimp viruses are known to pose a threat to human health (Kumpf et al. 1999).

Shrimp consumption in the U.S. has increased while the average annual domestic harvest has remained steady at approximately 200 million pounds (Kumpf et al. 1999). Growing demand for shrimp has been met by increasing imports (from Asia and South America) and expanding domestic aquaculture capacity. Unfortunately these activities increase the threat of exotic shrimp viruses entering processing and aquaculture facilities: viruses can enter processing facilities through infected imported or domestic shrimp, and likewise, can enter aquaculture facilities through infected brood stock, contaminated feed, infected transport containers, or by migratory birds.

There are three native penaeid shrimp species of commercial importance in the Gulf of Mexico – brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*Farfantepenaeus duorarum*), and white shrimp (*Litopenaeus setiferus*). The Gulf-region native shrimp fishery is economically significant; in Texas alone, it generates \$600 million in economic benefits annually and provides 30,000 jobs (GMP 1999). All three exotic shrimp viruses described above have been shown experimentally to infect the Gulf's three native penaeid shrimp species (Kumpf et al. 1999). The presence of exotic shrimp viruses at processing and aquaculture facilities increases the threat of

infecting wild native shrimp populations in the Gulf, potentially harming associated harvesting and processing industries.

In 1996, the Joint Subcommittee on Aquaculture, Shrimp Virus Workgroup conducted a workshop on the status of shrimp viruses in the Gulf of Mexico and Southeastern U.S. Atlantic Ocean, and the results of that workshop established the baseline information and action plan for dealing with the virus issue. Since that time additional Gulf-region workshops have been held and considerable new scientific research on shrimp viruses in the Gulf region has been conducted. Thus it is recommended that a new shrimp virus workshop be carried out in 2001 to bring all stakeholders up to date and to re-evaluate the approaches needed to address this important issue.

Ballast Water

Fundamental to world trade, ships have moved across the oceans for centuries and currently transport approximately 80 percent of the world's commodities (NRC 1996). Ballast, normally in the form of water, is an integral part of the safe operation of ships under a wide range of conditions and loads. The uptake, transport, and subsequent discharge of water and sediment from ship ballast tanks can disperse aquatic organisms – including jellyfish, crabs, clams, fish, snails, bacteria, and viruses. Research has confirmed that plants, animals, and pathogens can live and grow over a long period in ballast tanks and cargo holds (Smith et al. 1996). It has been estimated that more than 3,000 species of animals and plants are transported daily around the world in ballast water (NRC 1996). While the introduction of bacteria and viruses through ballast water is a growing concern (Associated Press 2000), its potential remains virtually unexplored by scientists (Ruiz et al. 2000). The potential for entire coastal planktonic assemblages to be introduced by international ballast water transfers, make bays, estuaries, and inland waters some of the most vulnerable ecosystems in the world (Carlton and Geller 1993).

Because of the lack of alternative ballast water control strategies, open-ocean exchange – exchanging ballast water loaded in port or in inshore waters with ocean water during passage between ports of call – is the only control option being implemented for reducing the risk of introduction. However, few studies have been conducted to determine the effectiveness of open-ocean exchange. This uncertainty combined with the fact that open-ocean exchange can compromise vessel safety and can be costly, particularly when exchange time exceeds voyage time, has led to the conclusion that open-ocean exchange is a short-term ballast water management approach.

This conclusion has prompted considerable research and investigations into other control options. Control options being investigated internationally include avoiding ballasting if water is likely to contain unwanted organisms (e.g., in areas of sewage discharge or high sediment loads) and shipboard and shore-based treatment of ballast water. Shore-based treatment of ballast may have some advantages, but centralized handling and treatment of such large volumes of water poses many economic and infrastructure challenges including, increased port congestion, lack of available land for treatment facilities, and delays in ship schedules. Although shipboard treatment also poses considerable challenges (e.g., space and energy limitations, shipboard safety), it currently provides the most flexibility in managing ballast water.

The diversity of potential introductions and the numerous environmental factors determining the fate of organisms discharged with ballast water make it difficult to predict what the next introduction will be or when and where it will occur (NRC 1996). To clarify the vulnerability of the Gulf of Mexico region, a better understanding is needed of (1) the nonindigenous species that have entered the Gulf region via ballast water and (2) each Gulf port's potential to serve as a conduit for future invasions. To begin this process, one recent study has estimated ballast water discharges to five major Gulf of Mexico ports (Table ES7). In addition, Barrett-O'Leary (1999) has prepared a white paper detailing a process to assess the potential for nonindigenous species introduction through U.S. Gulf of Mexico ports, which considers the following factors: total tonnage and total export tonnage; types and proportions of transport vessels and cargos; trade partners; origin of ballast; natural environment and port water quality compared to water quality of trade partners; and location of known pests and foulants in port.

Table ES7. Distribution of Cargo, Vessel Types, and Ballast Water Exchange for Five Major Gulf of Mexico Ports

Port	Cargo (million tons)	Type Vessel	Ballast Water Exchange
Houston	149	78% Tankers	3.7 million metric tons (1 billion gallons/yr)
New Orleans	83	37% Tankers 36% General Cargo	21.8 million metric tons (5.8 billion gallons/yr)
Gulfport	2.0	74% General Cargo	17.8 thousand metric tons (47 million gallons/yr)
Mobile	50.8	70% Bulk Carriers	1.1 million metric tons (293 million gallons/yr)
Tampa	51.3	52% Bulk Carriers	2.1 million metric tons (543 million gallons/yr)

Source: Kumpf et al. (1999)

Detailed ballast water information is now being collected under the National Ballast Water Survey. This survey is being conducted by the U.S. Coast Guard (USCG) to evaluate the level of ship compliance with the voluntary at-sea exchange guidelines for foreign vessel arrivals. Upon entry into U.S. ports, foreign vessels are required to submit a ballast water reporting form indicating whether an exchange has been conducted, and the volume and location of exchange. All information reported on the ballast water reporting form is recorded in the National Ballast Water Information Clearinghouse (NBWIC), operated and maintained by the Smithsonian Environmental Research Center (SERC). This information, combined with assessments of individual Gulf-region port vulnerabilities and a solid understanding of the nonindigenous aquatic organisms and their active introduction pathways, should allow regional managers to better control the ballast water pathway.

Three ballast water workshops have been held in the Gulf of Mexico region. During each workshop, national and regional perspectives on ballast water were shared during presentations made by the ports, the shipping industry, environmental managers, and scientists. Workshop participants also shared their opinions on regional management of ballast water and provided suggestions for future actions.

1.0 Scope and Purpose

1.1 Scope of this Report

Human activities have and continue to introduce – both deliberately and accidentally – a large number of new species to the Gulf of Mexico region. Many such nonindigenous species are greatly beneficial to society, providing much of the food we eat, sustaining significant sectors of our economy, offering recreational opportunities, and serving as pets in our homes and flora in our gardens. However, there is a harmful subset of these species – invasive species – that, when established as free-living populations beyond human control and confinement, can threaten the diversity of native species; the ecological stability of impacted ecosystems; economic activities dependent on these ecosystems; and human health.

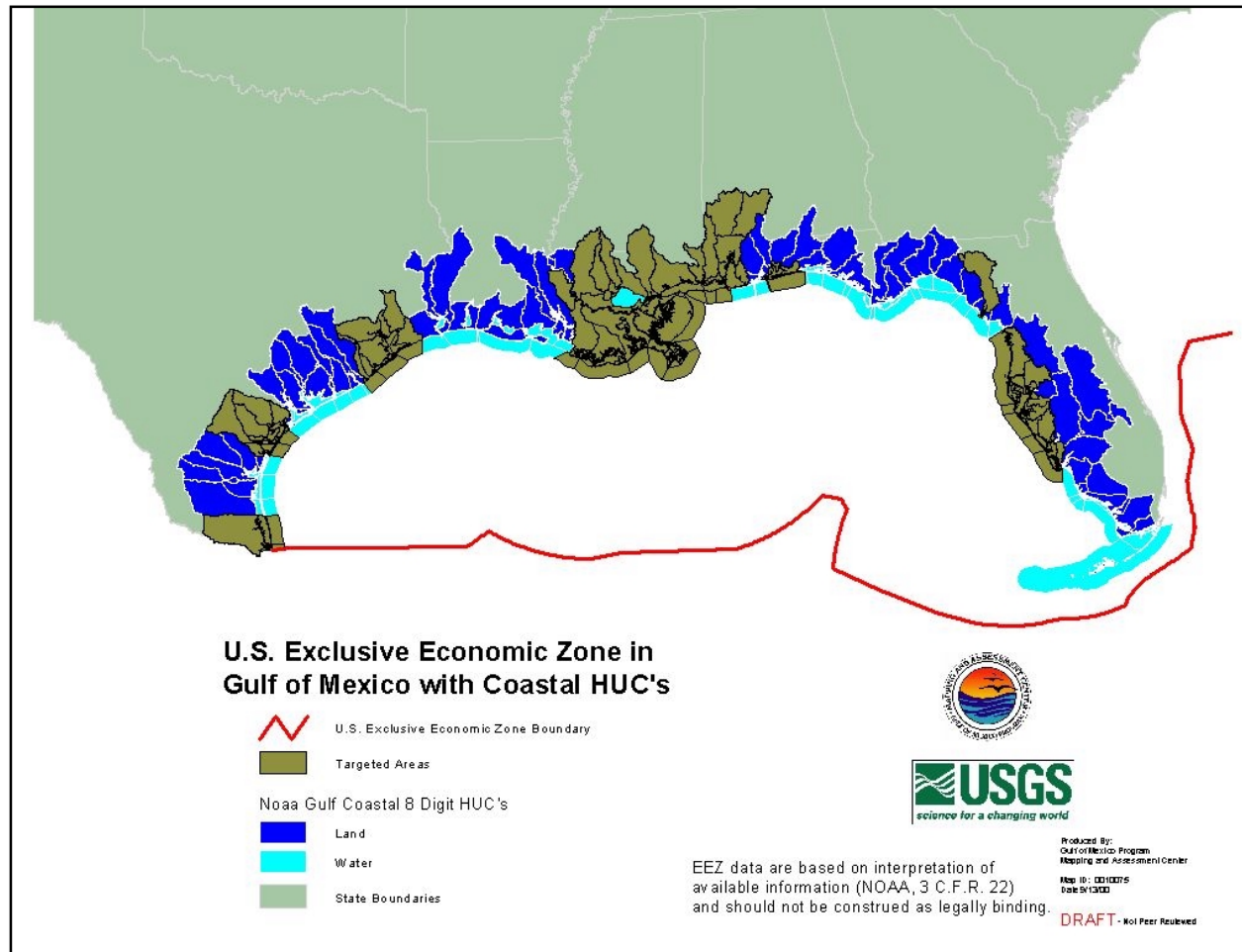
This report focuses on just those invasive species that are obligated to live in a waterbody for part or all of their lives: aquatic invasive species. Of all aquatic taxa, this initial survey concentrates on fish, non-insect aquatic invertebrates, aquatic mammals, aquatic microbes, and aquatic and semi-aquatic plants; it does not consider aquatic birds or aquatic insects.

In order to adequately survey aquatic invasive species issues, including potential future aquatic invasive species issues, in the Gulf of Mexico region, the scope of this report covers:

- Invasive nonindigenous aquatic species (1) established in free-living populations, (2) in a captive or managed state in the Gulf of Mexico region, or (3) not yet introduced to the Gulf of Mexico region, but with an active introduction pathway.
- Indigenous aquatic species aggressively expanding their natural ranges or density in an area due to human activities (*e.g.*, habitat alteration), to the detriment of other native species or ecosystems.
- Uncontrolled and unmonitored introductions of nonindigenous aquatic species, where there is no appropriate assessment of risks.

The large marine ecosystem that is the Gulf of Mexico contains two zoogeographic provinces, with tropical, subtropical, and temperate flora and fauna (Kumpf et al. 1999), shared among three countries, the U.S., Mexico, and Cuba. While Gulf-region managers must eventually consider this entire ecosystem and all three countries, this report focuses only on the U.S. portion of the Gulf of Mexico ecosystem. The study area for this report includes the area within the political boundaries of the five Gulf States – Florida, Alabama, Mississippi, Louisiana, and Texas – and waters of the Gulf of Mexico to the seaward boundary of the U.S. Exclusive Economic Zone (Figure 1).

Figure 1. Map of the Report Study Area: The Gulf of Mexico Region



Key Report Definitions

Despite previous attempts at standardization, terminology used to describe invasive species issues has not been applied consistently (Nico and Fuller 1999), in either the peer-reviewed or gray literature. Key terms used in the report are defined as follows (also see Section 11.0 Glossary):

Aquatic Species

All plants, animals, and microbes that are obligated to live in a freshwater, estuarine (*i.e.*, tidally-influenced), or marine waterbody (including a freshwater or coastal wetland) during all or part of their lives (adapted from Benson 2000).

Nonindigenous Species

Any individual, group, or population of a species, or other viable biological material, that is intentionally or unintentionally moved by human activities, beyond its natural range or natural zone of potential dispersal, including moves from one continent or country into another and

moves within a country or region; includes all domesticated and feral species, and all hybrids except for naturally occurring crosses between indigenous species. Introduced and non-native are synonyms for nonindigenous.

Pathway

The means by which a species enters an open ecosystem (adapted from McCann 1996). Vector is a synonym for pathway.

Introduction

The act of an organism being moved by either intentional and unintentional human-facilitated transference, including escape from confinement, to an area beyond its natural range or natural zone of potential dispersal. This definition does not include organisms imported and cultured in human control and confinement (e.g., aquaculture or research facility, ornamental pond), unless it escapes.

Established

A species with one or more successfully reproducing or breeding (*i.e.*, permanent) populations in an open ecosystem (*i.e.*, outside of human control and confinement), which are unlikely to be eliminated by man or natural causes. Naturalized is a synonym for established.

Invasive Species

A species that threatens the diversity or abundance of native species; the ecological stability of impacted ecosystems; economic activities (e.g., agricultural, aquacultural, commercial, or recreational) dependent on these ecosystems; and human health. Synonyms for invasive species include harmful species, injurious species, invader, noxious species, nuisance species, pest, and weed.

Gulf of Mexico Region

The Gulf of Mexico region includes the area within the political boundaries of the five Gulf States – Florida, Alabama, Mississippi, Louisiana, and Texas – and waters of the Gulf of Mexico to the seaward boundary of the U.S. Exclusive Economic Zone.

1.2 Purpose of this Report

The Gulf of Mexico is the ninth largest body of water in the world, with a surface area of approximately 1.5 million square kilometers, over 200 estuaries, an extensive barrier island system, and 5 million acres of coastal wetlands – nearly one-half of the U.S. total coastal wetland acreage (Kumpf et al. 1999). The 33 major river systems that comprise the Gulf of Mexico's U.S. watershed drain some 66 percent of the continental U.S. The Gulf of Mexico ecosystem provides one-third of all marine recreational fishing opportunities in the U.S., 72 percent of the U.S. shrimp harvest, and 66 percent of U.S. oyster production (Kumpf et al. 1999). It is a desirable place to live: population of the 50-mile-wide corridor along the entire Gulf coast is projected to increase by nearly 150 percent over the 50-year period ending in 2010 (Cato and Kumpf 1991).

The Gulf of Mexico Program (GMP) is a network of citizens dedicated to managing and protecting resources of the Gulf of Mexico in ways consistent with the economic well-being of the region (USEPA 1999). One goal of the GMP is to sustain living resources in the Gulf of Mexico. One mechanism to achieve this goal, the GMP will support implementation, by 2009, of voluntary or incentive-based practices and technologies that can prevent new introductions of invasive species, or reduce the impact or range of dispersal of known invasive species, as identified by the five Gulf States. By 2004, the GMP will assist each of the five Gulf States in developing a prevention, management, education, and monitoring plan to minimize introductions and impacts of invasive species.

To support Gulf-wide coordination and communication of invasive species issues, the GMP convened, beginning in 1997, a multi-stakeholder Invasive Species Focus Team (ISFT). While the Focus Team is a venue for all regional, state, and local invasive species problems, the ISFT is currently focused on three issues of Gulfwide importance: shrimp viruses, ballast water as a major introduction vector, and preventing new introductions of invasive species. The ISFT specifically assists the GMP by formulating technical characterizations, recommending annual program workplan goals, recommending priority projects, and developing a communication/public education program to address Gulf-region invasive species issues. The ISFT has also committed to serving as a resource to Gulf States preparing invasive species management plans, in accordance with the National Invasive Species Act (NISA) of 1996.

In 1999, the GMP Management Committee was designated to serve as the Gulf of Mexico Regional Panel to the national Aquatic Nuisance Species Task Force (ANSTF). The Gulf Regional Panel provides the ANSTF with regional input on emerging invasive species issues, coordinates regional invasive species control programs, and develops recommendations on policy and program actions to be implemented at the national level. The Gulf Regional Panel is also responsible for submitting an annual report to the ANSTF describing invasive species management activities in the Gulf region.

To meet these program responsibilities in a coordinated manner, the ISFT has developed this report to:

- Compile background and technical information needed to generate the Gulf Regional Panel's first (2000) Annual Report to the ANSTF;
- Begin compiling information that will assist the five Gulf States in developing aquatic components of their invasive species management plan(s);
- Generate a regional information and coordination resource for aquatic invasive species management and research activities, targeting the GMP's broad group of stakeholders.

The report is organized as follows:

- **Section 2.0** provides an introduction to the aquatic invasive species issue.
- **Section 3.0** provides a synthesis of aquatic species introduced to the Gulf of Mexico region, on a state-by-state basis (without regard to invasiveness).

- **Section 4.0** presents the results of a survey of aquatic invasive species management priorities in the five Gulf States.
- **Section 5.0** provides an overview of shrimp viruses, an issue of Gulfwide importance.
- **Section 6.0** provides an overview of ballast water as an introduction pathway, an issue of Gulfwide importance.
- **Section 7.0** outlines the current invasive species management framework at federal, regional, and state levels in the Gulf region.
- **Section 8.0** provides an inventory of recent major actions undertaken by regional stakeholders to address their aquatic invasive species issues.
- **Section 9.0** provides an inventory of abstracts from recently completed and current scientific research on selected aquatic invasive species issues. It also provides broad guidance for further scientific research in the Gulf region.
- **Section 10.0** provides specific recommendations for developing future versions of this document.
- **Section 11.0** provides a glossary of terms used in this document.
- **Section 12.0** provides bibliographic references.

In selected instances, this report incorporated recently published issue summaries to avoid duplication of effort. For example, descriptions of the shrimp virus sources and pathways in Section 5.2 were excerpted from JSA (1997). Similarly, descriptions of the federal-state management relationships in Section 7.4 and Appendices D, E, F, and G were adapted or excerpted from OTA (1993) and Corn et al. (1999). Now final, the Invasive Species Council report, *National Management Plan: Meeting the Invasive Species Challenge* (the final version – dated January 18, 2001 – is available at www.invasivespecies.gov), contains an extremely detailed description of the federal and international management framework for invasive species, and should serve as an excellent supplement to Section 7.0.

This report is current as of its completion date, September 2000. However, due to the highly dynamic nature of bioinvasions, new species introductions and management responses continue to occur. The ISFT intends this report to be a "living document," to be expanded and updated at the discretion of the ISFT.

2.0 *An Introduction to the Aquatic Invasive Species Issue*

2.1 Key Terminology

Humans have a long history of deliberately introducing terrestrial and aquatic species to new areas for agriculture, horticulture, soil conservation, sport fishing, hunting, pets, and a host of other reasons. These nonindigenous species are greatly beneficial to society, providing much of the food we eat, sustaining significant sectors of our economy, offering recreational opportunities, and serving as pets in our homes and flora in our gardens. At the same time, human activities like travel, trade, and natural habitat alteration have caused many unplanned or accidental introductions of species to new areas. The contemporary massive transformation of the natural environment and worldwide transport of people and cargo now facilitate species introductions – both deliberate and accidental – at a rate that completely overshadows natural rates of species movement (OTA 1993), and makes large-scale range expansions across mountains and oceans common. For the purposes of this report, we focus on these human-facilitated movements of species – both deliberate and accidental – to new areas: throughout this report such species are referred to as nonindigenous species.

For those nonindigenous species introduced to open ecosystems (i.e., outside of human control and confinement), only a portion will successfully establish one or more permanent, reproducing populations (Mack et al. 2000). These *established* nonindigenous species can be categorized by their impacts – ecologic and economic – in the new ecosystem: beneficial, harmful, unknown, or neutral (although, in many cases, impacts are a mix of beneficial and harmful) (OTA 1993). Many intentionally established nonindigenous species provide great benefit; see the sidebar “The Many Benefits of Nonindigenous Species Introduced to the U.S.” on Page 7. However, a small number of established nonindigenous species both intentionally and unintentionally introduced result in serious threats to the diversity or abundance of native species; the ecological stability of impacted ecosystems; economic activities (e.g., agricultural, aquacultural, commercial, or recreational) dependent on these ecosystems; and human health. The impacts of these few species is considerable; one study estimates that the overall economic impact of harmful nonindigenous species is a loss of more than \$138 billion per year (Pimentel et al. 1999). This report purposefully focuses on the small number of nonindigenous species that are harmful, or potentially harmful (i.e., those with unknown impacts), and does not further discuss beneficial nonindigenous species. Throughout this report, the term *invasive species* is used to denote those nonindigenous species with any form of harmful impact in open ecosystems.

The Many Benefits of Nonindigenous Species Introduced to the U.S.

Excerpted from OTA (1993).

Almost all economically important crops and livestock in the U.S. are nonindigenous species. Nonindigenous plants have a similarly important role in horticulture and include such familiar mainstays as iris (*Iris spp.*), forsythia (*Forsythia spp.*), and weeping willow (*Salix spp.*). Many plants used to prevent erosion are also nonindigenous, such as Bermuda grass (*Cynodon dactylon*) and lespedeza (*Lespedeza spp.*). Importation of new species and strains continues for the development of new varieties for agriculture, horticulture, and soil conservation. Nonindigenous insects also have important functions in agriculture. The European honey bee (*Apis mellifera*) forms the basis for the U.S. agriculture industry, providing bees to pollinate orchards and many other agricultural crops.

Nonindigenous organisms of many types have beneficial uses as biological control agents, frequently for control of nonindigenous pests. Insects and pathogens of plants and animals are most commonly used for control of weeds and insect pests. For example, a rust fungus (*Puccinia chondrillina*) was successfully introduced into California to control skeletonweed (*Chondrilla juncea*) in 1975. Fish have been introduced in some places to control aquatic weeds, mosquitoes, gnats, and midges. Some consider the introduction of barn owls (*Tyto alba*) to Hawaii to control mice and rats a success, although the use of land-dwelling vertebrates for biological control has generally caused great environmental damage.

A number of fish and shellfish cultured in the growing aquaculture industry are nonindigenous. Virtually the entire West Coast oyster industry is based on the Pacific oyster (*Crassostrea gigas*), originally from Japan. Fish species of tilapia, from Africa and the Middle East, are now commonly grown throughout the U.S., and shrimp farmers in southeastern and other regions of the country commonly raise Pacific white shrimp (*Litopenaeus vannamei*), a shrimp originally from Asia.

Sport fishing often means fishing for nonindigenous fish. The rainbow trout (*Oncorhynchus mykiss*), striped bass (*Morone saxatilis*), and varieties of largemouth bass (*Micropterus salmoides*), although indigenous to the U.S., have been widely introduced beyond their natural ranges for fisheries enhancement. A frequently stocked sport fish, the brown trout (*Salmo trutta*), originated in Europe. The Great Lakes salmon fishery is based on species indigenous to the Pacific coast of North America. Additional fish have been introduced to provide forage for game fish. Sport fishing not only provides recreational opportunities, but also stimulates the development of related businesses, such as boat rentals, charter fishing, and sales of fishing equipment and supplies.

Some of the most widely hunted game species, such as the chukar partridge (*Alectoris chukar*) and ring-necked pheasant (*Phasianus colchicus*), originated outside of the U.S. Sizable businesses exist to provide supplies and services for recreational hunting. Some nonindigenous big-game animals, like Sika deer (*Cervus nippon*) from Asia, and South African oryx (*Oryx gazella gazella*), are grown on private ranches for hunting, and also to satisfy the growing market for "exotic" game meats. Nonindigenous fur-bearing animals support both the trapping industry and fur-bearer farms.

Most pet and aquarium industries are based on domesticated and other nonindigenous species, including cats, dogs, hamsters, goldfish, snakes, turtles, and chameleons. These animals are valued by owners for companionship, protection, and recreation. A number of nonindigenous animals, such as the African clawed frog (*Xenopus laevis*), are used in biomedical fields for experimental work or testing.

Restoration of habitats degraded by pollution, mining, and other human disruptions sometimes includes planting stress-tolerant nonindigenous species. Several trees, like the ginkgo (*Ginkgo biloba*) from China, are common in urban landscaping, where few indigenous species can grow. Some nonindigenous sport fish serve a similar role in reservoirs and other artificial habitats less hospitable to indigenous species. Efforts to remedy environmental contamination from oil or other substances sometimes involve the release of nonindigenous microbes that accelerate contaminant degradation. Certain microbes help make nutrients available to plants through nitrogen fixation. These microbes also have been widely transferred and released around the world.

Paradoxically, nonindigenous species introductions are increasingly seen by some conservationists as a means to preserve certain endangered and threatened species that cannot be saved in their native habitats. Some conservationists have even suggested that introduction of large ungulates from Africa onto the American plains may be some species' best chance at survival.

Invasive Species: *A species that threatens the diversity or abundance of native species; the ecological stability of impacted ecosystems; economic activities (e.g., agricultural, aquacultural, commercial, or recreational) dependent on these ecosystems; and human health. Synonyms for invasive species include harmful species, injurious species, invader, noxious species, nuisance species, pest, and weed.*

It is important to understand the magnitude, origins, and pathways of nonindigenous species introductions to an open ecosystem, as these introductions form the “pool” of established nonindigenous species from which a few harmful invasive species arise. The remainder of Section 2.0 begins to explore these issues for the U.S., and Section 3.0 begins to explore these issues for the Gulf of Mexico region.

2.2 Characterizing Nonindigenous Aquatic Species Introductions to the U.S.

The Magnitude of Nonindigenous Aquatic Species Introductions to the U.S.

Researchers have documented a great increase in the number of nonindigenous aquatic species in the U.S. over the past 100 years (Benson 2000). Benson (2000) has inventoried 334 exotic aquatic amphibian, bryozoan, coelenterate, crustacean, fish, mammal, mollusk, plant, and reptile species introduced into the U.S., and 428 similar species transplanted within the U.S. (Table 1). Researchers predict that the effects of nonindigenous fishes on aquatic biodiversity will probably increase during the next 25 years because of the great increase in introduced fishes over the past 45 years (Fuller et al. 1999, Williams and Meffe 1999). Ruiz et al. (1997) contends that nonindigenous species are a significant force of change in marine and estuarine communities, fundamentally altering population, community, and ecosystem processes. Even though the number of fishes introduced to estuarine and marine systems worldwide appears to be small compared to the number in freshwater systems (Baltz 1991), Cohen and Carlton (1998) found an accelerating rate of aquatic invasions in the San Francisco Bay estuary.

Origin of Nonindigenous Aquatic Species Introductions to the U.S.

Introductions of nonindigenous aquatic species can be organized into two categories, based on where the species originates. The first is species having origins outside of the U.S. that enter the country, becoming established either under human cultivation (e.g., agriculture, horticulture, pets, etc.) or as independent, free-living populations. These species are defined as foreign or exotic species. The second category, defined as transplanted species, is a species having origins within the U.S. that is moved to an area beyond its native range.

At least one-half of all nonindigenous aquatic amphibians, crustaceans, fishes, mollusks, and reptiles introduced into U.S. waters, and more than 80 percent of the introduced aquatic plant species, are exotic (Table 1) (Benson 2000). Species from all taxonomic groups have come to the U.S. from South America, Central America, Asia, Europe, Africa, Australia, the Caribbean, the South Pacific, and the Pacific and Atlantic Oceans (Benson 2000). South America is the origin for the greatest number of U.S. nonindigenous aquatic species with 22 percent, followed

by Asia with 20 percent, Eurasia with 16 percent, Europe with 13 percent, Africa with 12 percent, Central America with 6 percent, and Australia with 2 percent (Benson 2000).

Table 1. Numbers of Nonindigenous Aquatic Species Introduced into the U.S.

	Foreign to the U.S.	Native to the U.S.
Amphibians	13	24
Bryozoans	1	2
Coelenterates	4	1
Crustaceans	15	15
Fishes	176	331
Mammals	1	0
Molluscs	29	7
Plants	74	15
Reptiles	21	33

Source: Benson (2000)

Determining the origin of some aquatic species becomes more problematic in estuarine and marine environments. It is assumed that centuries of ship traffic have brought numerous marine organisms (e.g., fouling and wood-boring invertebrates) to the U.S. and the Gulf region. Such species, established before the first surveys of marine taxa, are traditionally considered native, but there is little evidence whether they are native or introduced (Carlton and Ruckelshaus 1997). Until paleontological, archaeological, historical, biogeographic, systematic, or genetic evidence is available to further classify these organisms, they remain cryptogenic (i.e., a species whose status as indigenous or nonindigenous is not resolved) (Carlton and Ruckelshaus 1997).

Pathways of Nonindigenous Aquatic Species Introduction to the U.S.

A pathway, or vector, is the means by which a species enters an open ecosystem. Introduction pathways can be divided into three categories: unintentional, intentional, and escape from confinement (Williams and Meffe 1999). As a generalization, most plant and vertebrate animal introductions have been intentional, whereas most invertebrate and microbe introductions have been unintentional (Pimentel et al. 1999). Table 2 presents the principal pathways for aquatic species introductions categorized by this scheme. These pathways are described in more detail in Appendix A.

It should be recognized that many species have been intentionally introduced for beneficial reasons (e.g., increasing recreational fishing opportunities), only to later realize serious ecological and economic repercussions. Some infamous examples are grass carp (*Ctenopharyngodon idella*), introduced for aquatic weed control, kudzu (*Pueraria montana*), introduced for erosion control, and Chinese tallow tree (*Sapium sebiferum*), highly touted in Texas as fast growing shade trees during the 1970s (Stickney 2001). There are several such recreational fish species for which federal and state agencies established aggressive hatchery and distribution programs.

Table 2. Principal Pathways of Introduction for Aquatic Species

Pathway Category	Pathway of Introduction
Unintentional	<ul style="list-style-type: none"> • Transported Commodities • Vessels: Dry Ballast, Ballast Water, and Hull Fouling • Boat Trailers • Recreational Activities • Habitat Alteration / Canals • Interbasin Transfers of Water • Nontarget Species / Stock Contamination • Unknown
Intentional	<ul style="list-style-type: none"> • Agriculture, Horticulture, and Soil Conservation • Recreational Sport Fishing / Forage Species • Bait Bucket Releases • New Food Sources • Intentional Aquarium and Pet Releases • Biological Control • Species Conservation • Unknown
Escape from Confinement	<ul style="list-style-type: none"> • Horticulture • Ornamental Pond and Pet Escapes • Aquaculture and Fish Farms • Imported Live Food • Research / Public Display

Establishment of Nonindigenous Aquatic Species

Of all nonindigenous species introductions (terrestrial and aquatic) – both intentional and unintentional – only a subset persist and successfully reproduce (i.e., become established) in the new ecosystem (Mack et al. 2000). From the 50,000 terrestrial and aquatic nonindigenous species estimated by Pimentel et al. (1999) to have been introduced to the U.S., Williams and Meffe (1999) estimate that there are some 6,500 species of nonindigenous plants, animals, and microbes with established populations. Another study indicates that five to ten percent of introduced species (terrestrial and aquatic) become established, and two to three percent are able to expand their ranges (di Castri 1989). Nico and Fuller (1999) estimate that 38 percent of 185 exotic fish taxa introduced to U.S. inland waters have established or possibly established populations.

Invasiveness of Established Nonindigenous Aquatic Species

Only a subset of established nonindigenous species becomes invasive (Mack et al. 2000), although the impacts of many established nonindigenous species are a mix of beneficial and harmful, or remain unknown. Williams and Meffe (1999) estimate that, of the 6,500 established nonindigenous taxa (terrestrial and aquatic) in the U.S., about 15 percent are ecologically or

economically harmful. OTA (1993) estimates a range from 4 to 19 percent of nonindigenous terrestrial and aquatic species in the U.S. are harmful. Another study indicates that two to three percent of nonindigenous terrestrial and aquatic species expand their ranges (di Castri 1989). In Florida, 5 of the state's 20 established nonindigenous aquatic plant species are considered invasive (McCann et al. 1996).

Table 3 presents the number of nonindigenous aquatic species introduced to the U.S. by pathway. As indicated in Table 3, a wide variety of pathways facilitate introductions of nonindigenous fishes. A common pathway for a large number of species across varied aquatic taxa is aquarium and pet releases. As expected, the pathway of introduction remains unknown for a large number of species. Ruiz et al. (1997) contend that the global movement of ballast water currently appears to be the largest single vector for nonindigenous species transfer.

Table 3. Number of Nonindigenous Aquatic Species in the U.S. by Introduction Pathway

Pathway	Amphibians	Bryozoans	Coelenterates	Crustaceans	Fishes	Mammals	Molluscs	Reptiles
Unintentional								
Shipping	0	0	0	2	53	1	2	1
Ballast Water	0	0	4	5	7	0	3	0
Stock Contamination	2	0	0	1	31	0	1	0
Unknown	12	1	0	1	15	0	15	12
Intentional								
Sportfishing	0	0	0	0	114	0	0	0
Forage Species	0	0	0	1	47	0	0	0
Bait Bucket Releases	3	0	0	7	84	0	0	0
New Food Sources	1	0	0	0	19	0	0	2
Stocked	7	0	0	4	21	0	2	6
Aquarium and Pets	22	2	2	1	81	0	9	44
Biological Control	6	0	0	0	14	0	0	0
Conservation	0	0	0	0	21	0	0	0
Unknown	2	0	0	1	0	0	1	0
Escape from Confinement								
Ornamental	0	0	0	0	18	1	0	0
Imported Live Food	0	0	0	0	3	0	3	0
Aquaculture / Farms	0	0	0	2	54	1	1	0

Source: Adapted from Benson (2000)

It is important to realize that an established nonindigenous species can remain relatively contained for long periods of time, only later becoming invasive. Purple loosestrife (*Lythrum salicaria*) existed at low population levels and in a limited geographic area for decades before greatly expanding its range and becoming a widely recognized invasive species (Williams and

Meffe 1999). In other cases, the harmful effects of an established nonindigenous species can remain undetected for extended period (OTA 1993). Other nonindigenous species become problems only after an associated nonindigenous species is introduced (e.g., a plant's pollinator insect) (OTA 1993).

The impacts of a nonindigenous aquatic species can also be unknown (and therefore potentially invasive). For example in aquatic environments, of 111 fishes introduced in the U.S., 28 percent were found to have harmful effects, 30 percent to have beneficial effects, 17 percent both harmful and beneficial effects, and 25 percent unknown effects (OTA 1993). Of 88 mollusks analyzed in the same study, 44 percent were found to have harmful effects, 3 percent beneficial effects, and 53 percent unknown effects (OTA 1993). Steirer (1992) contends that most intentional aquatic introductions result in a mix of benefits and detriments, but no unintentional aquatic introductions have been considered beneficial.

Williams and Meffe (1999) have summarized the characteristics of invasive species and ecosystems subject to invasion (Tables 4a and 4b). Note, however, that the predictability of invasions remains limited in spite of well-established patterns of invasion (OTA 1993, Howells 1999).

Table 4a. Generalized Characteristics of Successful Invasive Species

- High rate of reproduction; pioneer species; short generation time
- Long-lived
- High dispersal rates
- Single-parent reproduction (for example, a gravid or pregnant female can colonize)
- Vegetative or clonal reproduction
- High genetic variability
- Phenotypic plasticity
- Broad native range
- Tolerant of wide range of conditions
- Habitat generalist
- Broad diet (polyphagous)
- Gregarious
- Human commensal

Table 4b. Generalized Characteristics of Communities More Likely to be Invaded

- Climatically similar to original habitat of invader
- Early successional (recently disturbed)
- Low diversity of native species
- Absence of predators on invading species
- Absence of native species morphologically (form or structure) or ecologically similar to the invader
- Absence of predators or grazers in evolutionary history (naïve prey)
- Absence of fire in evolutionary history
- Low-connectance food web
- Disturbed by humans

Source: Williams and Meffe (1999)

2.3 Impacts of Aquatic Invasive Species

Invasive species are one of six major components of global environmental change, and a significant contributor to the loss of biological diversity (Vitousek et al. 1996, Mack et al. 2000). While only a small number of all nonindigenous species introductions cause severe harm, such invasive species occur in almost all regions of the U.S. (OTA 1993). The major ecological impacts of invasive species are (1) outright loss of native species or decline in abundance of native species due to competition for food and space, predation, and habitat alteration; (2) changes in ecosystem structure and function, such as nutrient cycling and hydrology; (3) rearrangement of trophic relations; or (4) the introduction of virulent plant and animal diseases and parasites (Williams and Meffe 1999, Benson 2000, Mack et al. 2000). For example, two invasive fish species, grass carp (*Ctenopharyngodon idella*) and common carp (*Cyprinus carpio*), consume large quantities of aquatic vegetation, increase water turbidity, and generally destroy habitat for smaller fishes (Moyle et al. 1986). Genetic effects also occur through hybridization and interbreeding with native species (Mills et al. 1994).

Plants form the biological foundation of all terrestrial and freshwater communities, and invasive plant species can alter an ecosystem substantially, changing productivity, consumption, decomposition, water fluxes, nutrient cycling and loss, soil fertility, erosion, and frequency of fire (Schmitz et al. 1997). Invasive semi-aquatic trees such as Brazilian pepper (*Schinus terebinthifolius*) and Australian paperbark (*Melaleuca quinquenervia*) often form dense, single species stands, and constitute a serious threat to open marshlands and coastal shrub and strand communities of the Gulf of Mexico region (Cox 1999). In addition, chemicals from invasive organisms can adversely impact ecosystems. For example, various tannins and phenols in decaying leaves of the highly invasive Chinese tallow tree (*Sapium sebiferum*) are reported to be toxic to many aquatic invertebrates (Cox 1999).

Invasive species – both terrestrial and aquatic – can affect endangered and threatened species. Williams and Meffe (1999) report that invasive species contribute, at least in part, to the inclusion of about 315 U.S. native species and subspecies on federal endangered and threatened species lists. Of 30 extinct fishes in the U.S., invasive species were a factor in the extinction of 24 (Williams and Meffe 1999). Within rivers and lakes of Alabama (a Gulf state with a relatively large number of endemic freshwater invertebrates), 65 percent of gill-breathing snails and 69 percent of mussels are considered endangered, threatened, or of special concern (Minton 2000). It is feared that zebra mussels (*Dreissena polymorpha*), now established in northern Alabama, might invade Alabama's waters, displacing many of these endangered and threatened species (Minton 2000). Even seemingly insignificant species like the guppy (*Poecilia reticulata*) or mosquitofish (*Gambusia affinis*) have threatened native fishes and been implicated in the extinction of others (Howells 1999). Impacts on other species also can be indirect: the spread of horsetail Australian pines (*Casuarina equisetifolia*) on sandy coasts and barrier islands has altered the beach profile, hampering the ability of endangered loggerhead and green sea turtles to nest (Cox 1999, Williams and Meffe 1999).

Aquatic species introductions have both adversely and positively impacted local, regional, and national economies. Sport fishing, greatly enhanced by introductions of nonindigenous species, contributes \$69 billion annually to the U.S. economy. However, accounting for only

selected adverse ecological effects, one study estimates overall economic losses due to invasive fish introductions at more than \$1 billion per year (Pimentel et al. 1999). This same study estimates that the overall economic impact of nonindigenous species has been negative, contributing to a loss of more than \$138 billion per year (Pimentel et al. 1999). Within the aquatic environment, the highly invasive zebra mussel (*Dreissena polymorpha*) is expected to cost the power industry more than \$3 billion during the ten year period ending in 2003 (OTA 1993). It is estimated that \$100 million is spent annually to control aquatic weeds in the U.S. (OTA 1993). Florida alone spends about \$15.5 million each year on hydrilla (*Hydrilla verticillata*) control, yet infestations have caused an estimated \$10 million in annual recreational losses in just two Florida lakes (Center et al. 1997).

Adverse effects of introductions are not relegated to ecological and economic impacts: aquatic invasive species also have the potential to impact human health. For example, the Brazilian pepper tree (*Schinus terebinthifolius*), a significant problem in South Florida, produces allergens that cause contact dermatitis and respiratory problems in many people (Williams and Meffe 1999). An issue of Gulfwide concern is the introduction of aquatic invasive species through ballast water exchange. While the population did not proliferate, an exotic strain of *Vibrio cholerae*, the bacteria that causes cholera, was introduced to Mobile Bay in 1991 by ballast water exchange (McCarthy, pers. comm.). While the introduction of bacteria and viruses through ballast water is a growing concern (Associated Press 2000), its potential remains virtually unexplored by scientists (Ruiz et al. 2000).

History has demonstrated that those species with impacts to industry, commerce, and human health are the first to receive political attention, while species causing only ecological impacts remain unaddressed due to lack of financial incentives (OTA 1993). For example, water hyacinth (*Eichhornia crassipes*) and hydrilla (*Hydrilla verticillata*) are aquatic plants that significantly altered native ecosystems, but gained greater political visibility by being nuisances for recreational boaters and fishers (Benson 2000).

2.4 Control and Mitigation of Aquatic Species

Once a nonindigenous aquatic species becomes established, eradication is almost impossible in large aquatic ecosystems (Howells 1999, Benson 2000, Mack et al. 2000). Usually managers can only hope to control populations at economically or ecologically acceptable levels. However, recent history has demonstrated that control efforts can be enormously expensive, technologically impossible, harmful to nontarget species, and politically controversial (Simberloff 1997b, Devine 1998, Cox 1999).

Control is usually site-specific, and several methods are usually necessary (Benson 2000). Management and control should follow an integrated plan with the following components: prevention, assessment, site specific management, evaluation, monitoring, and education (Madsen 1997). National control programs exist for several aquatic species; for example, three aquatic plants currently in the U.S. Army's Corps of Engineer's Aquatic Plant Control Program are hydrilla (*Hydrilla verticillata*), water hyacinth (*Eichhornia crassipes*), and Eurasian watermilfoil (*Myriophyllum spicatum*) (Madsen 1997).

Invasive species control techniques can be categorized as either biological or nonbiological. Biological control is accomplished through the introduction of natural predators, diseases, or parasites that help keep the nuisance species in balance with its new environment (Benson 2000). Host-specificity between the pest and the biological control agent is necessary for effective biological control (Center et al. 1997). Several invasive aquatic plants, such as water hyacinth, hydrilla, alligatorweed (*Alternanthera philoxeroides*), and water lettuce (*Pistia stratiotes*) have been successfully controlled with introduced insects (Center et al. 1997). So far, though, researchers are having little success finding effective natural predators of other species, such as zebra mussels (Benson 2000).

Nonbiological control techniques can be categorized as either chemical or physical. Chemical control utilizes pesticides and herbicides to kill target organisms. In recent years fewer chemicals are available for aquatic use due to adverse effects on human health, aquatic ecosystems, and wildlife resources; there are currently six U.S. Environmental Protection Agency (USEPA)-approved herbicides for aquatic use (Madsen 1997). Physical techniques used to remove nonindigenous aquatic plants include hand-pulling, cutting, suction, rotovating, dredging, use of benthic barriers, light attenuation, and nutrient inactivation (Madsen 1997). Mechanical conveyors have long been used in South Florida to physically remove water hyacinth, one technique in an integrated control plan. Physical techniques used to control the zebra mussel include thermal, acoustic vibration, electrical current, filters and screens, coatings, toxic constructed piping, carbon dioxide injection, ultraviolet light, ozone, and anoxia/hypoxia (Benson 2000).

Control and management efforts should be an integral part of a comprehensive ecosystems restoration program. For example, a restoration project was undertaken at Hole-in-the-Doughnut, Everglades National Park, beginning in the 1970s. After several limited-success efforts to control invading Brazilian pepper trees using fire and herbicides, the removal of “rock-plowed soils” returned the area to a more natural state and significantly reduced Brazilian pepper infestations (Randall et al. 1997).

The need to address the adverse consequences of invasive species was officially recognized almost a century ago: the first legislation aimed at controlling unwanted introductions was the Lacey Act, passed in 1900. However, some researchers feel that current federal laws address only specific incidents and provide a remedy for only a small fraction of the invasive species problems (Williams and Meffe 1999). Even though southern Florida has been subject to relatively intense management for at least a decade, invasive species are currently invading every major ecosystem and converting large areas of natural ecosystems into new ecosystem types dominated by these new species (Cox 1999). Universally it is recognized that the prevention of new introductions of invasive species, and the immediate eradication of new colonies of invasive species, is the most effective, and cost effective, method to control invasive species (Mack et al. 2000).

3.0 Aquatic Species Introductions to the Gulf of Mexico Region

It is important to understand the magnitude, origins, and pathways of nonindigenous species introductions to an open ecosystem, as these introductions create the “pool” of established nonindigenous species from which harmful invasive species arise. Section 3.0 begins to explore these issues for the Gulf of Mexico region.

3.1 Aquatic Species Introductions to the Gulf of Mexico Region

Information to Assess Aquatic Species Introductions to the Gulf of Mexico Region

While datasets suitable for assessing nonindigenous aquatic species introductions are currently rare for the U.S. (Cohen and Carlton 1998), documentation of these species and their impacts is increasing rapidly as the adverse effects of invasive species become better recognized and appreciated. Several descriptions of the occurrence and status of nonindigenous aquatic species in Florida have been published (McCann et al. 1996, Simberloff et al. 1997, Goodyear 2000), but similar descriptions for other Gulf States and the Gulf of Mexico region as a whole are less frequent.

There are several existing and planned online resources. The U.S. Geological Survey (USGS) maintains an Internet-accessible database (<http://nas.er.usgs.gov>) of nonindigenous aquatic species that is searchable by state or by drainage (USGS 2000; see Fuller et al. 1999 and Benson 2000 for summaries of this dataset). The U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) maintains an extensive Internet-accessible database of plants that includes a searchable list of invasive species (USDA 1999). Both the USGS and NRCS websites provide access to digital distribution maps for selected species. The Center for Aquatic and Invasive Plants at the University of Florida maintains a descriptive online inventory of Florida’s invasive aquatic plant species (CAIP 2000). The GMP recently partnered with the Gulf Coast Research Laboratory Museum to develop a detailed online database of nonindigenous species (terrestrial and aquatic) in the Gulf of Mexico region (USM 2000).

The Magnitude of Aquatic Species Introductions to the Gulf of Mexico Region

Within the U.S., Florida and the Gulf Lowlands are second only to Hawaii in magnitude of nonindigenous species introductions (Cox 1999). The subtropical environment and abundant

aquatic habitats of the five Gulf States is naturally hospitable to nonindigenous aquatic species (Devine 1998, Cox 1999).

In 1990, 19 nonindigenous aquatic plant species were reported in Florida's public waters, placing Florida behind only Hawaii and perhaps California (McCann et al. 1996). Fuller et al. (1999) reported the number of nonindigenous fish species introduced into inland waters of Florida, Alabama, Mississippi, Louisiana, and Texas as 122, 53, 23, 28, and 105, respectively; at that time, the U.S. 50-state average was approximately 57 introductions per state. Table 5 presents a recent inventory of nonindigenous aquatic species introduced in the five Gulf States. These studies indicate that the total number of aquatic species introductions to Florida and Texas is nearly 2-3 times the U.S. 50-state average. See Section 3.2 for an updated inventory of nonindigenous aquatic species (including microbes, invertebrates, vertebrates, and plants) in the Gulf of Mexico region.

Table 5. Number of Nonindigenous Aquatic Species Introduced to each Gulf State Compared to the U.S. 50 State Average

State	Amphib -ians	Bryo- zoans	Coelent- erates	Crusta- ceans	Fishes	Mam- mals	Moll- uscs	Plants	Reptiles	TOTAL
AL	0	0	0	2	53	1	2	17	1	76
FL	13	0	0	3	123	1	9	60	16	225
LA	2	0	0	2	28	1	2	25	0	60
MS	0	0	0	2	23	1	2	10	0	38
TX	4	0	0	2	107	1	7	21	3	145
AVG.	1.5	0.1	0.3	2.6	59	0.4	3.3	8.7	1.8	~ 78

Source: Benson (2000)

Courtenay (1997) did not report any established nonindigenous marine fishes in Florida, noting that the complex life histories of these fishes may preclude colonization. However, several marine fishes, all released from aquariums, survive on coral reefs in Florida (Fuller, pers. comm.). For example, two orbiculate batfish (*Platax orbicularis*), a species from Indonesia, were collected from the Florida Keys; it was determined that these fish have resided here since 1994, and perhaps since 1989 (Fuller, pers. comm.). Some nonindigenous freshwater species established in Florida, such as blackchin tilapia (*Sarotherodon melanotheron*), have high salinity tolerance and have been reported in brackish waters (Baltz 1991). While numerous estuarine and marine invertebrates are established in the Gulf of Mexico region, there are no systematic studies of nonindigenous estuarine and marine invertebrates or plants in Florida waters (Carlton and Ruckelshaus 1997), or for the Gulf region.

Florida's rapidly expanding population has increased demand for development and water supplies, thus altering most of the natural ecosystems of southern Florida (McCann et al. 1996). These trends exist for the other four Gulf States, especially coastal areas. As a result, disturbed areas – urban, suburban, and rural – are now ideal sites for the establishment of nonindigenous plants and animals (McCann et al. 1996). Cox (1999) estimates that 27 percent of Florida's

current flora is nonindigenous. South Florida has proven particularly vulnerable to invasive species due to its insularity, tropical climate, and large area of disturbed habitat (Simberloff 1997a, Devine 1998). For example, in 1992, the South Florida Water Management District estimated that 26,000 acres were covered with stands of the Australian paperbark (*Melaleuca quinquenervia*). Today this highly invasive tree infects more than 500,000 acres of Florida south of Lake Okechobee (Cox 1999).

Pathways of Introduction to the Gulf of Mexico Region

The Gulf of Mexico region is vulnerable to aquatic species introductions due to the magnitude and variety of viable pathways created by, for example:

- Large numbers of people, vessels, and airplanes, and large volumes of cargo, coming through multiple large-scale, international ports and airports.
- Year-round, cross-state recreational boating, fishing, and other aquatic recreational activities.
- Due to the warm climate and proximity to tropical areas, numerous industries import, breed, grow-out, and warehouse a large variety of nonindigenous aquatic species.
- The Gulf Intracoastal Waterway and Mississippi River, which provide the 5 Gulf states with an aquatic connection to more than half of the 48 states in the continental U.S. In addition, the Tennessee-Tombigbee Waterway established a direct aquatic link between the Tennessee River and the Gulf of Mexico.

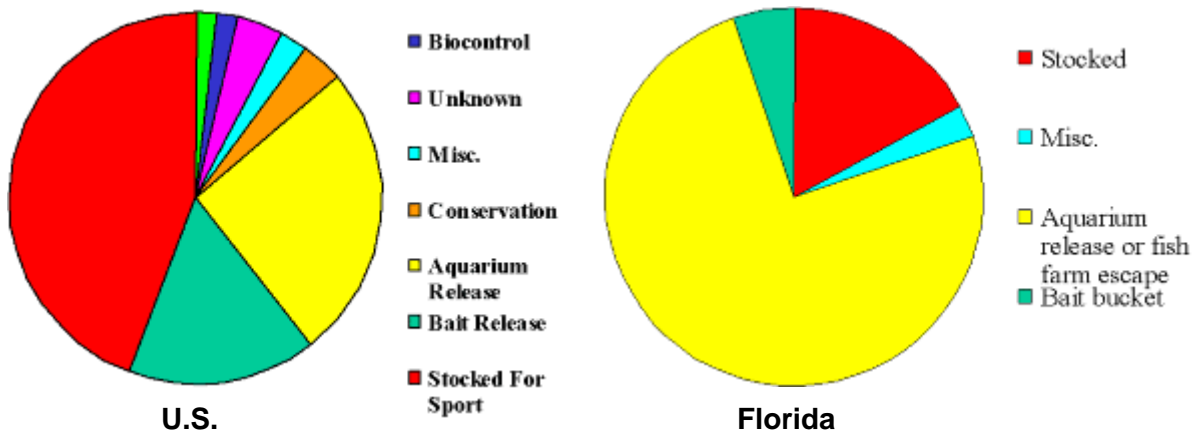
Nonindigenous fish have entered Gulf-region waters through a variety of pathways, including ballast water, bait bucket transfers, discarded aquarium pets, biocontrol efforts, sportfish stocking and stock contamination, aquaculture escapes, and stocking for food (Benson 2000) (see Appendix A for descriptions of these pathways). Pike killifish (*Belonesox belizanus*) were released in Florida after laboratory experiments at the University of Miami (Fuller, pers. comm.). Figures 2 and 3 demonstrate Florida's unique distribution of introduction pathways and species' origin for fish, relative to the U.S. A reason for at least part of these unique distributions is related to the zoogeography of Florida. The nonindigenous fish base of most states consists primarily of transplanted species, not foreign species, while Florida either already has many of these transplanted species as natives or has an unsuitable climate or habitats for them (e.g., salmonids) (Hill 2001).

A pathway of concern in Alabama is the introduction of aquatic invasive species through ballast water exchange (Minton 2000). While the population did not proliferate, strong evidence indicates that *Vibrio cholera*, the bacteria that causes cholera, was most probably introduced to Mobile Bay by ballast water exchange in 1991 (Minton 2000). Awareness of the significance of this pathway is greatly increasing throughout the Gulf region, and the ballast water pathway is a Gulfwide issue currently being addressed by the GMP Invasive Species Focus Team.

One pathway of special concern in the State of Texas is interbasin transfers of water (McKinney 2000). With water development infrastructure being constructed throughout Texas, the potential for rapid transfers of biota between river basins, and thus coastal bays, is increasing. The Texas Parks and Wildlife Department recently commissioned a study in an area where interbasin transfers will be likely, and found that risks were low for higher aquatic taxa (e.g.,

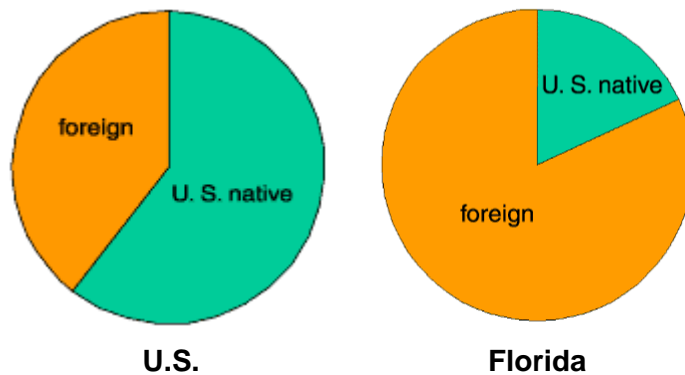
fish), but moderate for microbes and other lower taxa (McKinney 2000). This potential pathway exists in other parts of the Gulf of Mexico region, for example with the Tri-State Water Project for Alabama, Georgia, and Florida, and the Tennessee-Tombigbee Waterway.

Figure 2. Pathways of Fish Species Introductions in the U.S. and Florida



Source: P.L. Fuller and L.G. Nico, USGS Florida Caribbean Science Center, Gainesville, FL, from the South Florida Restoration Forum website (<http://sofia.usgs.gov/sfrsf/rooms/species/invasive/focus/>).

Figure 3. Origin of Introduced Fish Species in the U.S. and Florida



Source: P.L. Fuller and L.G. Nico, USGS Florida Caribbean Science Center, Gainesville, FL, from the South Florida Restoration Forum website (<http://sofia.usgs.gov/sfrsf/rooms/species/invasive/focus/>).

3.2 An Inventory of Nonindigenous Aquatic Species in the Gulf of Mexico Region

An Inventory of Nonindigenous Aquatic Species Occurring in the Gulf of Mexico Region of nonindigenous aquatic species occurrences in the five Gulf states was prepared for this report (Appendix B). This initial version of the inventory focuses on aquatic microbes, non-insect aquatic invertebrates, fishes, amphibians, aquatic reptiles, aquatic mammals, algae, aquatic

plants, and semi-aquatic plants; it does not inventory aquatic birds and aquatic insects, or any terrestrial species, in the Gulf region. The inventory compiles reports of nonindigenous aquatic species that occur or have occurred in all freshwater, estuarine, and marine environments in the Gulf of Mexico region, by Gulf State (note that an empty cell in the inventory does not necessarily mean that the species in question is not present in a given state). Information sources for each entry in the inventory are provided in the “Info Source” column in Appendix B.

Information for the inventory was gathered via Internet-based and other databases, and interviews with several Gulf-region experts (a primary information source was the USGS database described at the beginning of Section 3.1). The inventory is summarized in Tables 6, 7, 8, and 9.

Table 6. Number of Nonindigenous Aquatic Microbes Occurring (or Having Occurred at Least Once) in the Five Gulf States

State	Shrimp Viruses	Bacteria	Protozoa	Fungi	TOTAL
AL	*	1	2	*	3
FL	1	2	7	*	10
LA	*	*	2	*	2
MS	*	*	2	*	2
TX	3	1	1	*	5

* = None.

Table 7. Number of Nonindigenous Aquatic Invertebrates (Non-Insect) Occurring in the Five Gulf States

State	Tuni- cates	Bryo- zoans	Sponges	Coelen- terates	Flat- worms	Round- worms	Seg. Worms	Moll- usks	Crust- aceans	TOTAL
AL	*	*	*	1	*	*	*	3	3	7
FL	3	6	*	2	7	2	2	19	23	64
LA	*	*	*	*	*	*	*	3	5	8
MS	*	*	*	1	*	*	*	2	2	5
TX	1	*	*	*	*	1	*	9	5	16

* = None.

Table 8. Number of Nonindigenous Aquatic Vertebrates Occurring in the Five Gulf States

State	Fishes	Amphibians	Reptiles	Mammals	TOTAL
AL	51	*	1	1	53
FL	117	13	18	1	149
LA	27	2	*	1	30
MS	22	*	*	1	23
TX	98	4	3	1	106

* = None.

Table 9. Number of Nonindigenous Aquatic Plants Occurring in the Five Gulf States

State	Algae	Aquatic Vascular Plants	Semi-Aq. Vascular Plants	TOTAL
AL	1	25	6	32
FL	2	45	23	70
LA	1	34	10	45
MS	1	25	7	33
TX	2	30	12	41

Some Notes about Creating the Inventory

In general, there is adequate information available about the occurrence of nonindigenous aquatic invertebrates (excluding insects) and vertebrates in the Gulf of Mexico region. Likewise, there is abundant information available for nonindigenous aquatic plants, with many government, university, and private websites listing, describing, and picturing species.

The USGS Nonindigenous Aquatic Species database, a primary information source for the Inventory, tracks the spatial and temporal distribution of all introduced aquatic organisms. This includes introductions of species from foreign countries as well as native species transplanted outside of their native range in the U.S. The database tracks all incidents of introductions, whether or not the introduction results in an established population. This allows for a better understanding of pathways, source regions, and spatial patterns of introductions. The majority of the data in the database is derived from published, peer-reviewed literature, but also includes reports from state and federal natural resource agencies and personal communications from knowledgeable field biologists.

It appears that much less effort has been expended to identify nonindigenous microbes occurring in the Gulf of Mexico region, probably due to the complexity of the task. As there are few Internet-based sources of information on the occurrence of nonindigenous microbes in the Gulf of Mexico region, the species included in the Inventory were compiled through the volunteer efforts of a number of regional microbiology experts. It is important to highlight several notes about these species.

According to Carol Shieh, a U.S. Food and Drug Administration virologist at the Gulf Coast Seafood Laboratory, little effort has been spent researching nonindigenous aquatic viruses; the obvious exceptions are the three nonindigenous shrimp viruses identified in the Gulf-region (Shieh, pers. comm.). Two bacteria with nonindigenous strains in the Gulf of Mexico region have been studied. There is a toxigenic strain of *Vibrio cholerae* that is indigenous to the Gulf of Mexico region. However, the epidemic strain, *V. cholerae*, serotype Inaba, biotype El Tor, is exotic, and was introduced in ballast water (McCarthy, pers. comm.). Similarly, *Vibrio parahaemolyticus* occurs ubiquitously. However, the O3:K6 serotype that caused the Texas and

New York outbreaks is probably exotic since it was never reported in the U.S. before (McCarthy, pers. comm.). It has proven difficult to keep track of this strain because it undergoes frequent genetic changes (McCarthy, pers. comm.). Many terrestrial fungi are capable of living in aquatic environments and, as a generality, it is difficult to determine which fungi species are nonindigenous (McCarthy, pers. comm.). Protozoa listed in the inventory consist primarily of fish parasites.

4.0 Aquatic Invasive Species Management Priorities in the Five Gulf States

"It has gone berserk. It's like the Blob... The willows, the hollies, the cabbage palms - they're being buried alive."

Joel Achenbach, Washington Post, July 30, 2000
Of Old World climbing fern (*Lygodium microphyllum*) in the Everglades

Sections 4.1 through 4.5 present the results of interviews with Gulf State agency representatives on the GMP Invasive Species Focus Team to identify aquatic invasive species that are **current management priorities** or **potential future management priorities** in each of the five Gulf States. Section 4.6 provides summary tables of information in Sections 4.1 to 4.5. In some cases, as noted below, the interviewed state agency representatives sought the input of a larger group of state stakeholders, while in other cases interview results represent the opinions of one agency representative. The interviews were intended to produce a representative, rather than comprehensive, list of Gulf-region management priorities. The ISFT intends to conduct a more formal and extensive survey for future compilations of this information.

For the purposes of the interviews, "current management priority" is defined as an invasive, or potentially invasive, aquatic species that the state is most concerned with managing at the present time. "Potential future management priority" is defined as an invasive, or potentially invasive, aquatic species that (1) does not yet occur in the state, but that has an active introduction pathway, or (2) already has been introduced to the state, and is of concern due to the magnitude of adverse impacts experienced in similar ecosystems. It is critical to recognize that management priorities can be based on the actual or perceived threat a species poses, even though it does not yet occur in the state. Similarly, invasive or potentially invasive species that already occur in a state may not necessarily be a management priority in that state.

Selected Gulf State agency representatives on the ISFT prepared and presented invasive/nonindigenous species "status presentations" at the Nonindigenous Species Focus Group Panel Session at the Gulf of Mexico Symposium, Mobile, Alabama, April 10-12, 2000. In most cases, summaries from these presentations, distributed at the Panel Session, served as the foundation for follow-up interviews with these same representatives.

In all interviews the following information was requested for a each species recognized as a current or potential future management priority: species common name; species scientific name; place of origin; confirmed, suspected, or potential introduction pathway(s); biological and/or economic rationale for concern (potential impacts); impacts experienced; management status in the state; and current control/prevention strategies. However, only the information provided by

the interviewee is documented in the following sections. In several cases only the species name was provided.

4.1 Aquatic Invasive Species Management Priorities in Alabama

Vernon Minton, Marine Resources Division, Alabama Department of Conservation and Natural Resources (ADCNR) summarized Alabama's aquatic invasive species management priorities as follows (Minton 2000; note that not all literature citations and personal communications in Minton 2000 are not provided in Section 12 References of this document). The list was supplemented with comments from Steve Health, Marine Resources Division, ADCNR, and Pam Fuller, USGS.

Invertebrates

- The zebra mussel (*Dreissena polymorpha*) has established itself in the Wheeler Reservoir of the Tennessee River in North Alabama and in the lower Mississippi River, and may in time reach the lower Mobile Delta. However, zebra mussels have not multiplied to the extent seen in northern parts of the country. Whether it can survive in Mobile Bay, where it will confront moderate to high salinities and predators such as black drum (*Pogonias cromis*), is unknown. A recent report by Deborah Wills stated that Alabama is home to 43 percent of the native freshwater gill-breathing snails and 60 percent of the native freshwater mussels found in the U.S. (Wills 2000). Of those, 77 percent of the snails and 34 percent of the mussels are endemic to Alabama, or the river system shared by Alabama and a neighboring state (Wills 2000). Unfortunately, the report also states that 65 percent of the snails and 69 percent of the mussels are considered either endangered, threatened, or of special concern (Wills 2000). Research will have to determine if zebra mussel infestations would displace native mussels.
- Spotted jellyfish (*Phyllorhiza punctata*) (Fuller, pers. comm.)

Fishes

- The bighead carp (*Hypophthalmichthys nobilis*) has been reported frequently in public waters. The biological impact of bighead carp is unknown; further research on the potential impacts on other filter-feeding fishes, such as the paddlefish (*Polyodon spathula*), bigmouth buffalo (*Ictiobus cyprinellus*), and gizzard shad (*Dorosoma cepedianum*), is needed. We have observed, however, that bighead carp is frequently caught with the paddlefish in main channel habitats.

Aquatic Plants

- Hydrilla (*Hydrilla verticillata*) is distributed throughout Alabama.
- Giant salvinia (*Salvinia molesta*) was identified in March 1999 in a 7-acre golf course pond in Auburn. It is likely that it existed here since at least 1997. A flood event in July 1999 dispersed these plants to the drainage below the golf course; giant salvinia is now found at

two impounded tributaries of Sougahatchee Creek. In August 1999, giant salvinia was reported from a 3.8 acre pond draining Uchee Creek, north of Seale, Alabama. By December 1999, plants were believed to have been carried, perhaps by animals such as racoons or turtles, upslope from the Seale pond to a smaller pond nearby.

- Water hyacinth (*Eichhornia crassipes*) (Heath, pers. comm.)

Potential Future Aquatic Invasive Species of Concern

There are several potential invertebrate invaders of concern in Alabama:

- The chocolate brown blue crab (*Callinectes bocourti*) usually does not venture further north than Belize, but this species typically co-occurs with the blue crab (*Callinectes sapidus*) in its natural habitat. One individual was collected in Alabama coastal waters in the summer of 2000 (Heath, pers. comm.).
- The jellyfish (*Drymonema dalmatinum*), colloquially referred to as the “pink meanie” or the “pink insullation jellyfish,” was collected in Alabama coastal waters in the summer of 2000 (Heath, pers. comm.).
- The Chinese mitten crab (*Eriocheir sinensis*) has not yet been reported in Alabama, but it is a species of concern due to its highly invasive nature.
- While there is no record of green crab (*Carcinus maenus*) in Alabama, it is a potential future management concern.
- Asian clam (*Corbicula fluminea*) (Fuller, pers. comm.)
- Grass carp (*Ctenopharyngodon idella*) (Fuller, pers. comm.)
- Silver carp (*Hypophthalmichthys molitrix*) (Fuller, pers. comm.)

Introduction Pathways of Special Concern

- A management concern is the introduction of aquatic invasive species through ballast water exchange. While the population did not proliferate, strong evidence indicates that *Vibrio cholera*, the bacteria that causes cholera, was most probably introduced to Mobile Bay by ballast water exchange in 1991.

4.2 Aquatic Invasive Species Management Priorities in Florida

Invertebrates

Daniel Roberts, Dan Marelli, David Camp (retired), and William G. Lyons (retired), from the Florida Marine Research Institute, summarized Florida’s invasive invertebrate species management priorities as follows (Roberts 2000). This list is admittedly focused on estuarine and marine species; future versions of this report will give equal focus to Florida’s freshwater invasive species management priorities.

- The green mussel (*Perna viridis*), a marine mussel (>20 ppt), is a confirmed invasive species. Ecosystem effects include conversion of planktonic carbon to benthic carbon and possible competition for space with natural fouling organisms on red mangrove prop roots. Individuals were discovered in Tampa Bay in late 1999, but possibly were introduced in 1998. A spawning population has been confirmed, as is the ability of this tropical mussel to overwinter in Tampa Bay. The green mussel has been found throughout Tampa Bay, in the Gulf of Mexico as far west as Anna Maria Island, and in Sarasota Bay. It is expected to populate many substrates in Tampa Bay and be exported to other Florida harbors.
- The Asian clam (*Corbicula fluminea*) is currently found in many freshwater lakes and streams in north Florida. It is suspected to have been brought to the U.S. in the 1920s for use as a food source. Potential ecosystem effects include competition for space with native freshwater mussels, many of which are endangered or threatened.
- Conrad's (or dark) falsemussel (*Mytilopsis leucophaeata*) is native to Florida, but a facultative mollusk of concern. It occurs on hard substrates in coastal ponds, lakes, and rivers from 2-5 ppt. Recently, these mussels have been found throughout the Caloosahatchee river and in southern Lake Okeechobee. They have also been seen in the King's Bay region of Crystal River. Upstream invasions are likely because of increasing dissolved solids as a result of human activities (e.g., fertilizer). This problem will continue and expand unless discharges and runoff are controlled.
- Salle's (or Santa Domingo) falsemussel (*Mytilopsis sallei*) may or may not be native to Florida (i.e., cryptogenic). It occurs in southeastern Florida and possibly was introduced by shipping sometime in the past 500 years. It has habitat requirements similar to those of Conrad's falsemussel (*Mytilopsis leucophaeata*), and has invaded upstream in the Caloosahatchee River.
- The saber crab, or river crab, (*Platychiropsus spectabilis*) is native to eastern Mexico and west Africa (Rathbun 1914, In: Marchand 1946). The crab was apparently introduced to the Hillsborough River by vessels delivering cedar logs for the manufacture of cigar boxes. It is known to be riverine, but some local scientists think part of its life cycle is estuarine. This crab is not found in large numbers and impact appears to be minimal.
- The West Indian trochid (*Cittarium pica*), a gastropod, was found at Marathon and Molasses Keys in the Florida Keys. The species may be established, but may disappear as it did in Bermuda. Natural recruitment might be responsible for appearance of this species, which may be recruiting from planktonic larvae spawned in the Caribbean basin (Abbott 1976).
- In April 1995, both male and egg-bearing female marine swimming crabs (*Charybdis helleri*) were caught in traps in the Indian River Lagoon. This crab lives throughout the Indo-Pacific area from the east coast of Africa to Hawaii. Juveniles and one ovigerous female in the Indian River leave no doubt that a reproducing population exists, if not an established one. This crab has not been found in the Gulf of Mexico yet. However, its aggressive nature and migration patterns in other parts of the world (e.g., through the Suez Canal to the Mediterranean Sea) have scientists anticipating further distribution and colonization into the Gulf of Mexico (Camp 1997).
- The marine nudibranch (*Glossodoris sedna*), native to the tropical eastern Pacific Ocean, was found in Tavernier Key, Florida (Bertsch 1988). Only a few specimens were found.

Fishes

Daniel Roberts, Dan Marelli, David Camp (retired), and William G. Lyons (retired), from the Florida Marine Research Institute, summarized Florida's invasive fish species management priorities as follows (Roberts 2000). This list is admittedly focused on estuarine and marine species; future versions of this report will give equal focus to Florida's freshwater invasive species management priorities.

- Mozambique tilapia (*Oreochromis mossambicus*) are common in southeast Florida coastal canals and in Tampa Bay. They range west through the state, but east and west coast populations do not seem to be confluent. Each of the sites where Mozambique tilapia has been collected represent a different source of introduction (Courtenay et al. 1974; Shafland, pers. comm., June 9, 1997).
- The blackchin tilapia (*Sarotherodon melanotheron*) was the first tilapia species to become established in Florida (Springer and Finucane 1963 In: Shafland 1996). It is distributed in Brevard and Indian River Counties on the east coast, and Tampa Bay on the Gulf coast. It is extensively associated with brackish water. Although the Gulf coast population has been locally successful in Tampa Bay, it has not extended its range significantly for 30 years (Shafland 1996).
- The Mayan cichlid (*Cichlasoma urophthalmus*) is quite common in southwestern Florida, where they inhabit mangroves, and has spread south of the Tamiami Trail (U.S. 41). According to Shafland (1996) this species may contribute substantially to the forage base for tarpons and snooks, and they may prey on those same species as well depending on size interaction. Mayan cichlid supports a limited sport fishery in some areas as it readily takes artificial baits. In some areas it is the most common fish caught on hook-and-line. It fights hard and has an attractive snapper-like appearance (Shafland 1996).
- Two nonindigenous populations of the Asian swamp eel (*Monopterus albus*) recently were discovered in Florida in 1997 (Tampa and Miami areas). USGS field data indicates that the species is locally abundant and reproducing (Nico 1999). Based on literature and preliminary findings, the swamp eel appears to have the potential to colonize and adversely affect natural wetlands in the Everglades and other systems in the southeastern U.S. (Nico 1999).
- Walking catfish (*Clarias batrachus*)
- Spotted tilapia (*Tilapia mariae*)
- Pike killifish (*Belonesox belizanus*)

Aquatic Plants

Eleven invasive aquatic plant species are listed by the Florida Exotic Pest Plant Council as Category I plants, capable of disrupting aquatic ecosystems (FDEP 2000). These species are actively controlled in public waters by the Aquatic Plant Management Section, Bureau of Invasive Plant Management, Florida Department of Environmental Protection.

- The highest priority species for control in Florida's public waters are water hyacinth (*Eichhornia crassipes*) and waterlettuce (*Pistia stratiotes*). Managers brought these two

species under control during the late 1980s and have sustained these low levels through the 1990s (Schardt 1999).

- Hydrilla (*Hydrilla verticillata*) is distributed statewide, highly invasive, and a current high priority species for control. Insufficient funding allowed hydrilla to expand from 50,000 to 140,000 acres in the 1990s (FDEP 2000).
- Two occurrences of giant salvinia (*Salvinia molesta*) in Florida were identified and removed (Schardt, pers. comm.). While an herbicide eradication program exists for this species, there is considerable concern about its spread. Weed Alert, an awareness-building campaign, exists for giant salvinia. It is suspected that waterspinach is planted by some Asian communities for food.
- While an herbicide eradication program exists for waterspinach (*Ipomoea aquatica*), there is considerable concern about its spread. Weed Alert, an awareness-building campaign, exists for waterspinach.
- Aquatic nightshade (*Solanum tampicense*)
- Hygro, or Indian swampweed, (*Hygrophilia polysperma*)
- Paragrass (*Brachiaria mutica*)
- Torpedograss (*Panicum repens*)
- West Indian marshgrass (*Hymenachne amplexicaulis*)
- Wild taro (*Colocasia esculenta*)
- Alligatorweed (*Alternanthera philoxeroides*), until recently a high priority invasive species, has been brought under control by a suite of three insects (Schardt 1999).

Semi-Aquatic Plants

The Upland Plant Management Section, Bureau of Invasive Plant Management, Florida Department of Environmental Protection funds individual invasive plant removal projects on public conservation lands throughout the state. Several high priority species for management readily thrive in semi-aquatic habitats.

- Weed Alerts, an awareness-building campaign, are ongoing for catclaw mimosa (*Mimosa pigra*) and melaleuca (*Melaleuca quinquenervia*) (Schardt, pers. comm.). An herbicide eradication program exists for both species.
- Australian pine (*Casuarina equisetifolia*)
- Brazilian pepper tree (*Schinus terebinthifolius*)

Potential Future Aquatic Invasive Species

Daniel Roberts, Dan Marelli, David Camp (retired), and William G. Lyons (retired), from the Florida Marine Research Institute, summarized some of Florida's potential future invasive invertebrate and fish species management priorities as follows (Roberts 2000). This list is admittedly focused on estuarine and marine species; future versions of this report will give equal focus to Florida's freshwater invasive species management priorities.

- The veined rapa whelk (*Rapana venosa*) inhabits sandy substrates in estuaries and nearshore marine environments. It is a voracious marine predator that prefers bivalves such as the hard clam (*Mercenaria mercenaria*) and the Atlantic oyster (*Crassostrea virginica*). Research needs to determine if it will compete with native predators for food. It is presently limited to Chesapeake Bay, but is likely to be transported to the Indian River system.
- The zebra mussel (*Dreissena polymorpha*) [and the quagga mussel (*Dreissena bugensis*)] inhabit hard substrates in freshwaters to brackish waters less than 2 ppt. These mussels have caused over \$400 million in human impacts in just over ten years of invasion of the Great Lakes, St. Lawrence, and Mississippi River systems. They also are interfering with native unionid freshwater mussels in many systems. Mussels are easily transported between water bodies on and in boats and other vessels and with bait, aquatic vegetation, diving gear, etc. They are unlikely to become widespread in Florida because of high summer temperatures and low pH in many waterbodies. However, some Florida lakes and spring run rivers are vulnerable to zebra mussel invasion. Efforts to prevent such invasions need to be initiated, including examining incoming boats and trailers and quarantining freshwater bait from areas where zebra mussels have become established.
- The black-lipped pearl oyster (*Pinctada margaritifera*) is an extremely valuable organism, probably capable of surviving in South Florida and the Caribbean. It is reported to occur near Palm Beach off of southeastern Florida. Research needs to determine if it will compete with native fauna.
- Many attempts have been made to create sterile hybrids of the Japanese oyster (*Crassostrea gigas*) because of its excellent taste and rapid growth rate (adults of over 15 cm are not uncommon). Triploid hybrids have been generated and are in widespread aquaculture use in the Pacific Northwest; however, the production of triploids has not totally resulted in sterile populations. Research needs to determine if culture of these animals would increase the potential for release of viable oysters. Research also needs to determine if this species will directly compete with the native Atlantic oyster (*Crassostrea virginica*).
- Giant clams (*Tridacna crocea* and *Tridacna maxima*) are valuable organisms for food, shells, and as an aquarium species. Trade in some species is restricted by international agreement. Others can be purchased live via the Internet. Potential impacts are unknown.
- An Asian mytilid freshwater mussel (*Limnoperna fortunei*) occupies lakes, ponds, and rivers attached to hard substrates. This species has been recently introduced to Argentina and Brazil; it appears to be the tropical and warm-temperate ecological equivalent of the zebra mussel. There is nothing to prevent this species from invading Florida freshwaters. The organism is causing widespread problems in South America; research needs to determine potential impacts in Florida.
- Pacific white (or whiteleg) shrimp (*Litopenaeus vanammei*) have not been reported in Florida waters. However, there is concern about an accidental release from a one billion post larval per year hatchery on Summerland Key.
- Blue tilapia (*Oreochromis aureus*) has been documented throughout central and south Florida (smaller populations are found further north), and in estuarine waters on both the Atlantic Ocean and Gulf of Mexico coasts. The species is tolerant of brackish water salinities and cool water. Shafland (1996) points out that the species is also successful in terms of standing crop: it often exceeds 20 percent of total fish biomass. While blue tilapia

have occurred in Florida for about 40 years, there are few published data documenting adverse effects in Florida freshwaters (Hill 2001). It is a popular recreational and commercial species in freshwater and brackish areas. Wild and farmed tilapia are sold in restaurants and grocery store outlets throughout Florida. Weekend fishermen in Tampa Bay fish for tilapia for food and sport with both cast nets and hook-and-line gear.

- Grass carp (*Ctenopharyngodon idella*) (Roberts, pers. comm.). Triploid grass carp are widely used under permit from the Florida Fish and Wildlife Conservation Commission for the control of aquatic macrophytes (Hill 2001). Diploid stocks may be maintained only under permit by aquaculture and research facilities (Hill 2001).

Jeff Schardt, Bureau of Invasive Plant Management, Florida Department of Environmental Protection, and Herb Kumpf, NMFS, identified Florida's potential future invasive aquatic plant species management priorities as follows:

- A bloom of nitrogen-fixing blue-green algae (*Cylindrospermopsis raciborskii*), native to Australia, has persisted for at least two years in Lake Griffin (SJRWMD 1999). The St. John's River Water Management District is working to restore this degraded lake (Schardt, pers. comm.).
- A tropical green algae (*Caulerpa toxifolia*) (Kumpf, pers. comm.)

4.3 Aquatic Invasive Species Management Priorities in Louisiana

The State of Louisiana's Department of Wildlife and Fisheries, assisted by the Louisiana Sea Grant Program and Louisiana State University, is in the process of convening an Aquatic Nuisance Species Task Force (an organizational meeting was held in August 2000) (Biggar, pers. comm.). Once representation from other state agencies and organizations is established, the Task Force will begin to work on a state management plan. One of the first tasks of the Task Force will be to identify aquatic invasive species of concern: this list will be included in potential future versions of this document.

Mammals

The adverse impact of nutria (*Myocastor coypus*) on Louisiana marshes is well documented (TNCL 1999). The Louisiana Department of Wildlife and Fisheries, working with state and federal agencies, as well as private companies, has developed a set of management recommendations for nutria.

Fishes

Charlie Biggar (Inland Fisheries Division, Louisiana Department of Wildlife and Fisheries) summarized Louisiana's invasive fish species management priorities as follows:

- Rio Grand cichlid (*Cichlasoma cyanoguttatum*)
- Grass carp (*Ctenopharyngodon idella*)
- Silver carp (*Hypophthalmichthys molitrix*)
- Bighead carp (*Hypophthalmichthys nobilis*)

Aquatic Plants

Richard Brasseur (Aquatic Plant Control Section, Louisiana Department of Wildlife and Fisheries), Charlie Biggar (Inland Fisheries Division, Louisiana Department of Wildlife and Fisheries), and the Nature Conservancy of Louisiana (TNCL 1999) summarized Louisiana's invasive aquatic plant species management priorities as follows:

- Alligatorweed (*Alternanthera philoxeroides*) (Biggar, pers. comm.)
- Water hyacinth (*Eichhornia crassipes*) (Brasseur, pers. comm., TNCL 1999)
- Hydrilla (*Hydrilla verticillata*) (Brasseur, pers. comm., TNCL 1999)
- Torpedograss (*Panicum repens*) (Biggar, pers. comm.)
- Water lettuce (*Pistia stratiotes*) (Biggar, pers. comm.)
- Giant salvinia (*Salvinia molesta*) (Brasseur, pers. comm., TNCL 1999)
- Common salvinia (*Salvinia minima*) (Brasseur, pers. comm.)

Semi-Aquatic Plants

- Kudzu (*Pueraria montana*) (TNCL 1999)
- Chinese tallow tree (*Sapium sebiferum*) (TNCL 1999)

Potential Future Aquatic Invasive Species of Concern

Potential future introductions of several species were identified as management priorities at a recent GMP-sponsored workshop (GMP 1997). The Nature Conservancy of Louisiana also identified some relatively new species expected to become serious problems in the near future (TNCL 1999).

- Zebra mussels (*Dreissena polymorpha*) exist in the Mississippi River in southern Louisiana. There is concern about the potential spread of this species (TNCL 1999). The opening of the Bonne Carre spillway (Lake Pontchartrain) and other proposed freshwater diversions the species has new routes to the Gulf of Mexico (GMP 1997).
- Brown (or Mexihalo) mussel (*Perna perna*) (GMP 1997)
- Marine swimming crab (*Charybdis helleri*) (GMP 1997)
- Chinese mitten crab (*Eriocheir sinensis*) (GMP 1997)
- European green crab (*Carcinus maenas*) (GMP 1997)
- Asian clam (*Corbicula fluminea*) (Biggar, pers. comm.)
- Spotted jellyfish (*Phyllorhiza punctata*) (Biggar, pers. comm.)

- Black carp (*Mylopharyngodon piceus*) (GMP 1997)
- Round goby (*Neogobius melanostomus*) (GMP 1997)
- Cogongrass (*Imperata cylindrica*) (TNCL 1999)
- Purple loosestrife (*Lythrum salicaria*) (TNCL 1999)

4.4 Aquatic Invasive Species Management Priorities in Mississippi

The following multi-agency group summarized Mississippi's aquatic invasive species management priorities, presented in this section:

- Henry Folmar, Mississippi Department of Environmental Quality
- Tom Van Devender, Mississippi Department of Marine Resources
- Ron Garavelli, Dennis Riecke, and Todd Slack, Mississippi Department of Wildlife, Fisheries, and Parks
- Mark LaSalle, Mississippi Sea Grant Program
- Cynthia Moncrief, University of Southern Mississippi Gulf Coast Research Laboratory
- David Felder, Mississippi Department of Environmental Quality

Invertebrates

- The spotted jellyfish (*Phyllorhiza punctata*), native to Australia but present in the Caribbean Sea for several years now, showed up in the northern Gulf of Mexico in large numbers in 2000. The organism grows to 2 to 3 feet in diameter and is a voracious feeder on plankton. These organisms may compete with other plankton feeding organisms, and at high densities could alter the composition of the plankton community. They have also caused fouling of fishing nets and propellers. First seen in the northern Gulf of Mexico (Mobile Bay area) in May of 2000, it remains to be seen if these organisms will successfully overwinter (Graham, pers. comm.).
- Zebra mussels (*Dreissena polymorpha*) have been found in the Mississippi River, the associated oxbow lakes that form Mississippi's western border, and in the Tennessee River in the northeast corner of the state. There are well documented problems with this species competing with native species, fouling water intakes, screens, and other structures.

Fishes

- Nile tilapia (*Oreochromis niloticus*), an aquacultured species in Mississippi, have been collected in the wild. There is concern that they are able to overwinter in thermal discharges in the coastal rivers. Todd Slack, State Ichthyologist for Mississippi, and Mark Peterson, Gulf Coast Research Lab, have submitted a proposal to study the effect of tilapia on gamefish in coastal Mississippi. Blue tilapia (*Oreochromis aureus*) and Mozambique tilapia (*Oreochromis mossambicus*) are both aquacultured species in Mississippi, but no officially documented species have been collected in the wild at this time (Slack, pers. comm.).

Mammals

- Nutria (*Myocastor coypus*) are widespread across the southern states, and compete with native muskrats and beavers. They cause problems by destroying wetland and crop vegetation, burrowing into levees, and carrying diseases.

Aquatic Plants

- The aquatic fern, giant salvinia (*Salvinia molesta*) has been found in Mississippi, and is of concern because of problems observed in Texas, Louisiana, and other southern states with similar habitats. It shades out desirable native species, interferes with fishing, and may reduce the quality of wetlands as waterfowl habitat.
- Hydrilla (*Hydrilla verticillata*) is a very aggressive invasive species forming thick mats that shade out native vegetation. It has been found in Aliceville Reservoir on the Tennessee-Tombigbee Waterway, and is reported from other locations across the state. It is often accidentally transported from one waterbody to the next on boats or trailers.
- Water hyacinth (*Eichhornia crassipes*), a free-floating plant much like giant salvinia, is present in several drainages of Mississippi. Water hyacinth infestations are of concern as they can reduce fisheries, block boat traffic, shade out submerged plants, and reduce biological diversity.

Semi-Aquatic Plants

- The Chinese tallow tree (*Sapium sebiferum*) is extremely invasive in a variety of habitats, from upland to wetland.

Potential Future Aquatic Invasive Species of Concern

- The round goby (*Neogobius melanostomus*), a fish native to Eurasia, was introduced into the Great Lakes Region, probably via ballast water around 1990. The species does well in both freshwater and saltwater, and is spreading rapidly in the Great Lakes. It is reported to be interfering with the walleye fishery in Lake Michigan. There is concern that the organism will spread south via the Mississippi River.
- The Asian swamp eel (*Monopterus albus*) is spreading rapidly in south Florida and has been reported in the Chattahoochee River system in north Georgia. The swamp eel does well in lakes, ponds, rivers, and swamps. Because it has the ability to breathe out of the water, it can cross short distances of dry ground.
- Black carp (*Mylopharyngodon piceus*) is an Asian carp that feeds predominantly on mollusks. This fish is being used by catfish farmers in the Mississippi Delta to control snails as part of an integrated management strategy to control a yellow grub disease. This species of fish has not been collected from Mississippi waterways, but there is concern that, if it escaped, it could further reduce populations of rare or endangered mollusks, and that it would compete with native fishes with a similar feeding habit. However, the Mississippi Department of Wildlife, Fisheries, and Parks and the Department of Agriculture and

Commerce have an approved management plan for black carp (Avery 2001). In addition, black carp have been cultured in Arkansas since its importation by the U.S. Fish and Wildlife Service in the late 1960s, and there has not been a report of escapement (Avery 2001).

4.5 Aquatic Invasive Species Management Priorities in Texas

Dr. Larry McKinney, Senior Director of Water and Resource Protection at Texas Parks and Wildlife Department (TPWD) summarized Texas' aquatic invasive species management priorities as follows (McKinney 2000). The list is supplemented, as noted, with input from Dr. Earl Chilton (TPWD), other TPWD staff, and other experts.

Microbes

- Introductions of diseases associated with nonindigenous shrimp (i.e., Taura Syndrome Virus, White Spot Syndrome Virus, and white-spot-like viruses), is an issue of concern in Texas.

Invertebrates

- The Pacific giant (or Japanese) oyster (*Crassostrea gigas*) is of concern because of disease potential and potential competition with native oysters.
- Channeled applesnail (*Pomacea canalicula*) (Chilton, pers. comm.)

Fishes

- The grass carp (*Ctenopharyngodon idella*) is established in the Galveston Bay system. This species has been identified as the primary culprit in the failure of numerous marsh revegetation projects in the upper reaches of the system. Grass carp have been reported in several other coastal bay systems. The release of triploid grass carp are permitted by TPWD for vegetation control, and approximately 1,000 permits per year are issued (Chilton, pers. comm.). The release of diploid grass carp is prohibited, as is the release of triploid grass carp without a permit (Chilton, pers. comm.).
- Mozambique tilapia (*Oreochromis mossambicus*) and blue tilapia (*Oreochromis aureus*) are established in many Texas power plant cooling reservoirs, but have not expanded outside those systems. Both of these species have been recorded in routine sampling of bayous emptying into the Galveston Bay system.
- The Rio Grande cichlid (*Cichlasoma cyanoguttatum*) is native to southern waters in Texas, but has been documented in other systems, such as Galveston Bay.
- Nutria (*Myocastor coypus*)

Aquatic Plants

- Water hyacinth (*Eichhornia crassipes*)
- Hydrilla (*Hydrilla verticillata*)
- A large infestation of giant salvinia (*Salvinia molesta*) was discovered and treated in eastern Texas in 1999. This infestation represents the first documented large-scale occurrence of this plant in Texas.
- While cryptogenic at this point, the persistent brown tide (*Aureoumbra lagunensis*) in the Laguna Madre system, the longest continuous algal bloom ever recorded, might be a aquatic invasive species issue requiring management
- The Chinese tallow tree (*Sapium sebiferum*) has invaded coastal prairies and freshwater wetland areas in Texas (Moulton, pers. comm.).
- Alligatorweed (*Alternanthera philoxeroides*) (Chilton, pers. comm.)
- Waterlettuce (*Pistia stratiotes*) (Chilton, pers. comm.)
- Common salvinia (*Salvinia minima*) (Chilton, pers. comm.)

Potential Future Aquatic Invasive Species of Concern

- In the past, the brown (or Mexihalo) mussel (*Perna perna*) has been widely distributed from the mid-Texas coast south into Mexico. Populations have fluctuated in past years, however, they seem to have more recently disappeared (Tunnell, pers. comm.). Past invasions appear to have been associated with currents bringing the mussels from Mexican waters (Tunnell, pers. comm.).
- American eels (*Anguilla rostrata*) were cultured in Texas on one occasion. The exotic nematode, *Anguillicola crassus*, was found in some eels imported from the U.S. east coast for use in culture ponds. To date, no native eels have been found to have this parasite.
- The potential introduction of zebra mussel (*Dreissena polymorpha*) is of concern.
- Asian clam (*Corbicula fluminea*) (Fuller, pers. comm.)
- Marine swimming crab (*Charybdis helleri*) (Chilton, pers. comm.)
- Chinese mitten crab (*Eriocheir sinensis*) (Chilton, pers. comm.)
- European green crab (*Carcinus maenus*) (Chilton, pers. comm.)
- Spotted jellyfish (*Phyllorhiza punctata*) (Chilton, pers. comm.)
- Silver carp (*Hypophthalmichthys molitrix*) (Chilton, pers. comm.)
- Bighead carp (*Hypophthalmichthys nobilis*) (Chilton, pers. comm.)
- Black carp (*Mylopharyngodon piceus*) (Chilton, pers. comm.)
- Successful establishment of waterspinach (*Ipomoea aquatica*) is of concern.
- Purple loosestrife (*Lythrum salicaria*) (Chilton, pers. comm.)
- Kudzu (*Pueraria montana*) (Chilton, pers. comm.)

- New introductions of pathogens, viral and other, is an invasive species issue of concern. The cryptogenic nature of these organisms makes it difficult to know if the situation is one of introduction or observed manifestation of an indigenous species. Related to this concern are bacteria mixes used for biological control of oil spills. Because these are often proprietary in nature and their use is for emergencies, control is problematic unless addressed in advance.

Introduction Pathways of Special Concern

- Interbasin transfers of water is a pathway of special concern in Texas. Texas Parks and Wildlife Department has commissioned a study to assess that risk in one region of the state where interbasin transfers will be likely. Preliminary results indicate that risks are low for higher taxa, such as fish, but moderate for microbial and other aquatic taxa.

4.6 Summary Tables: Aquatic Invasive Species Management Priorities in the Gulf of Mexico Region

Tables 10 and 11 summarize the invasive aquatic plant and animal species identified as management priorities in Sections 4.1 to 4.5.

Table 10. Current and Potential Future Management Priorities in the Five Gulf States, September 2000: Invasive Aquatic and Semi-Aquatic Plant Species.

SCIENTIFIC NAME	COMMON NAME	AL	FL	LA	MS	TX
<i>Alternanthera philoxeroides</i>	alligatorweed		√	√		√
<i>Aureoumbra lagunensis</i>	brown tide algae					√ ^a
<i>Brachiaria mutica</i>	paragrass		√			
<i>Casuarina equisetifolia</i>	Australian pine		√			
<i>Caulerpa toxifolia</i>	tropical green algae		P			
<i>Colocasia esculenta</i>	wild taro		√			
<i>Cylindrospermopsis raciborskii</i>	blue-green algae		P			
<i>Eichhornia crassipes</i>	water hyacinth	√	√	√	√	√
<i>Hydrilla verticillata</i>	hydrilla	√	√	√	√	√
<i>Hygrophila polysperma</i>	Indian swampweed		√			
<i>Hymenachne amplexicaulis</i>	West Indian marshgrass		√			
<i>Imperata cylindrica</i>	cogongrass			P		
<i>Ipomoea aquatica</i>	waterspinach		√			P
<i>Lythrum salicaria</i>	purple loosestrife			P		P
<i>Melaleuca quinquenervia</i>	paperbark (melaleuca)		√			
<i>Mimosa pigra</i>	catclaw mimosa		√			
<i>Panicum repens</i>	torpedograss		√	√		
<i>Pistia stratiotes</i>	waterlettuce		√	√		√
<i>Pueraria montana</i>	kudzu			√		P
<i>Salvinia minima</i>	common salvinia			√		√
<i>Salvinia molesta</i>	giant salvinia	√	√	√	√	√
<i>Sapium sebiferum</i>	Chinese tallow tree			√	√	√
<i>Schinus terebinthifolius</i>	peppertree		√			
<i>Solanum tampicense</i>	wetland nightshade		√			

Source: This information was provided by representatives of Gulf State agencies and organizations on the Gulf of Mexico Program Invasive Species Focus Team. At this time, it is intended to be a representative, rather than comprehensive, list of management priorities.

√ = Current management priority in the state.

P = Potential future management priority for the state.

Note: Designations are not based on occurrence in the state, but rather priorities for management. Some of the unchecked species exist in the state, but are not currently considered priorities for management.

^a = Cryptogenic (a species whose status as indigenous or nonindigenous remains unresolved)

Table 11. Current and Potential Future Management Priorities in the Five Gulf States, September 2000: Invasive Aquatic Animal Species.

SCIENTIFIC NAME	COMMON NAME	AL	FL	LA	MS	TX
<i>Anguillicola crassus</i>	exotic nematode on American eels					P
<i>Belonesox belizanus</i>	pike killifish		√			
<i>Callinectes bocourti</i>	chocolate brown crab	P				
<i>Carcinus maenus</i>	green crab	P		P		P
<i>Charybdis helleri</i>	marine swimming crab		√	P		P
<i>Cichlasoma cyanoguttatum</i>	Rio Grande cichlid			√		√
<i>Cichlasoma urophthalmus</i>	Mayan cichlid		√			
<i>Cittarium pica</i>	West Indian trochid		√			
<i>Clarias batrachus</i>	walking catfish		√			
<i>Corbicula fluminea</i>	Asian clam	P	√	P		P
<i>Crassostrea gigas</i>	Japanese (or Pacific giant) oyster		P			√
<i>Ctenopharyngodon idella</i>	grass carp	P	P ^a	√		√
<i>Dreissena polymorpha</i>	zebra mussel	√	P	P	√	P
<i>Drymonema dalmatinum</i>	jellyfish	P				
<i>Eriocheir sinensis</i>	Chinese mitten crab	P		P		P
<i>Glossodoris sedna</i>	marine nudibranch		√			
<i>Hypophthalmichthys molitrix</i>	silver carp	P		√		P
<i>Hypophthalmichthys nobilis</i>	bighead carp	√		√		P
<i>Limnoperna fortunei</i>	freshwater mussel		P			
<i>Litopenaeus vannamei</i>	Pacific white (or whiteleg) shrimp		P			
<i>Monopterus albus</i>	swamp eel		√		P	
<i>Mylopharyngodon piceus</i>	black carp			P	P	P
<i>Myocastor coypus</i>	nutria			√	√	√
<i>Mytilopsis leucophaeata</i>	Conrad's (or dark) false mussel		√			
<i>Mytilopsis sallei</i>	Salle's (or Santa Domingo) false mussel		√ ^b			
<i>Neogobius melanostomus</i>	round goby			P	P	
<i>Oreochromis aureus</i>	blue tilapia		P			√
<i>Oreochromis mossambicus</i>	Mozambique tilapia		√			√
<i>Oreochromis niloticus</i>	Nile tilapia				√	
<i>Perna perna</i>	brown (or Mexihalo) mussel			P		P
<i>Perna viridis</i>	green mussel		√			
<i>Phyllorhiza punctata</i>	spotted jellyfish	√		P	√	P
<i>Pinctada margaritifera</i>	black-lipped (or Pacific) pearl oyster		P			
<i>Platychoirograpsus spectabilis</i>	saber crab		√			
<i>Pomacea canalicula</i>	channeled applesnail					√
<i>Rapana venosa</i>	veined rapa whelk		P			
<i>Sarotherodon melanotheron</i>	blackchin tilapia		√			
Taura Syndrome Virus	shrimp virus					√
<i>Tilapia mariae</i>	spotted tilapia		√			
<i>Tridacna spp.</i>	giant clams		P			
White Spot Syndrome Virus	shrimp virus					√

Table 11, continued. Current and Potential Future Management Priorities in the Five Gulf States, September 2000: Invasive Aquatic Animal Species, cont.

Source: This information was provided by representatives of Gulf State agencies and organizations on the Gulf of Mexico Program Invasive Species Focus Team. At this time, it is intended to be a representative, rather than comprehensive, list of management priorities.

√ = Current management priority in the state.

P = Potential future management priority for the state.

Note: Designations are not based on occurrence in the state, but rather priorities for management. Some of the unchecked species exist in the state, but are not currently considered priorities for management.

^a = Diploid stocks only.

^b = Cryptogenic (a species whose status as indigenous or nonindigenous remains unresolved)

5.0 Gulfwide Issues Addressed by the ISFT: Shrimp Viruses

To support Gulf-wide coordination and communication of invasive species issues, the GMP sponsors a multi-stakeholder Invasive Species Focus Team (ISFT). While the Focus Team serves as a venue for all regional, state, and local invasive species problems, the ISFT is currently focused on three issues of Gulfwide importance: shrimp viruses, ballast water as an introduction vector, and the prevention of new introductions of invasive species. To date, the majority of the Focus Team's efforts have been concentrated on the first two issues. Section 5.0 provides an overview of the shrimp virus issue in the Gulf of Mexico region and highlights efforts to address the issue.

In 1996, the Joint Subcommittee on Aquaculture, Shrimp Virus Workgroup conducted a workshop on the status of shrimp viruses in the Gulf of Mexico and Southeastern U.S. Atlantic Ocean, and the results of that workshop established the baseline information and action plan for dealing with the virus issue. Since that time additional Gulf-region workshops have been held and considerable new scientific research on shrimp viruses in the Gulf region has been conducted. Thus it is recommended that a new shrimp virus workshop be carried out in 2001 to bring all stakeholders up to date and to re-evaluate the approaches needed to address this important issue.

5.1 Overview of the Shrimp Virus Issue

Of the 14 penaeid shrimp viruses known worldwide, three exotic viruses have been identified in the Gulf of Mexico region: White Spot Syndrome Virus (WSSV), Taura Syndrome Virus (TSV), and Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHNV). Another exotic shrimp virus, Yellow Head Virus (YHV), usually co-occurs with WSSV (Lightner 1996a, Lightner 1996b), but has not been identified in live shrimp in the Gulf of Mexico region (McIlwain, pers. comm.). WSSV is endemic throughout much of Asia, and TSV and IHHNV are endemic in wild shrimp populations throughout much of Central and South America (JSA 1997). It has been shown that all three viruses are carried by some live shrimp, but they also have been found in imported frozen shrimp, shrimp by-products, and in a number of non-penaeid shrimp and other crustacean species (e.g., copepods, crabs, and crayfish) (Lightner 1996a, Lightner 1996b, JSA 1997). Note that none of these three exotic shrimp viruses are known to pose a threat to human health (Kumpf et al. 1999).

Shrimp consumption in the U.S. has increased while the average annual domestic harvest has remained steady at approximately 200 million pounds (Kumpf et al. 1999). Growing demand for shrimp has been met by increasing imports (from Asia and South America) and expanding

domestic aquaculture capacity. Unfortunately these activities increase the threat of exotic shrimp viruses entering processing and aquaculture facilities: viruses can enter processing facilities through infected imported or domestic shrimp, and likewise, can enter aquaculture facilities through infected brood stock, contaminated feed, infected transport containers, or by migratory birds.

In 1997, there were almost 400 shrimp harvesting and processing (non-aquaculture) businesses located in the five Gulf States, with more than two-thirds (268) located in Louisiana and Texas (JSA 1997). To date, no processing facilities in the Gulf region have reported the presence of exotic shrimp viruses. However, little testing for viruses of shrimp product, solid waste, or wastewaters from these facilities is undertaken (Treece and Johnson, pers. comm.). One recent study found WSSV in 8 of 10 samples from lots of imported frozen shrimp tails (Durand et al. 2000), and the study authors contend that because the U.S. imports thousands of tons of cultured shrimp each year, frozen imported shrimp are a probable source for the introduction of WSSV into the Americas.

Exotic shrimp viruses have decimated stocks at a few Gulf region aquaculture facilities, bringing economic hardship to those businesses. WSSV, first identified in Asia in 1992, appeared in cultured white shrimp (*Litopenaeus setiferus*) in three Texas shrimp ponds in 1995 (Kumpf et al. 1999, Treece, pers. comm.). These ponds were drained and dried, and WSSV has not been reported again in commercial facilities in Texas (Treece, pers. comm.). Outbreaks of TSV, first identified in Ecuador, occurred at shrimp farms in Texas in 1995 and 1996 (JSA 1997). However, TSV has likely been eliminated in Texas' commercial channels of livestock through the USDA High Health and Genetically Improved stock program (Treece and Johnson, pers. comm.). One chapter in Fulks and Main (1992) reported IHNV occurring in Texas and Florida shrimp aquaculture facilities (JSA 1997).

There are three native penaeid shrimp species of commercial importance in the Gulf of Mexico – brown shrimp (*Farfantepenaeus aztecus*), pink shrimp (*Farfantepenaeus duorarum*), and white shrimp (*Litopenaeus setiferus*). The Gulf-region native shrimp fishery is economically significant; in Texas alone, it generates \$600 million in economic benefits annually and provides 30,000 jobs (GMP 1999). All three exotic shrimp viruses described above have been shown experimentally to infect the Gulf's three native penaeid shrimp species (Kumpf et al. 1999). The presence of exotic shrimp viruses at processing and aquaculture facilities increases the threat of infecting wild native shrimp populations in the Gulf, potentially harming associated harvesting and processing industries.

There is little information on the presence of exotic shrimp viruses in populations of native shrimp in the Gulf region. Since initiating investigations in 1998, Texas Parks and Wildlife Department has regularly found a white-spot-like virus in native Gulf shrimp (Treece, pers. comm.). However, the results have not been published and may be given an accurate presentation by TPWD in the future (Johnson, pers. comm.). A researcher at Texas A&M University looked at live shrimp from bait stands in three Texas ports and diagnosed at least one group as having a white-spot-like virus, however, further samples from these bait stands did not show the presence of virus (Treece, pers. comm.). In 1996, wild native white shrimp (*L. setiferus*) introduced to a Texas A&M University research facility in Port Aransas were found to

be infected with a white-spot-like virus (Treece, pers. comm.). Fortunately the exotic shrimp (*Litopenaeus vannamei*) at the research facility were not exposed to the WSSV-infected wild *L. setiferus* and, therefore, did not develop the disease. Similar to concerns of processing and aquaculture facilities being a vector for virus transmission to wild shrimp populations, shrimp aquaculturists have fears of diseased wild native shrimp exposing their cultured stocks to viruses (Treece, pers. comm.).

Specifics on the Shrimp Virus Issue in Texas

Despite the fact that WSSV, TSV, and IHNV have occurred at Texas aquaculture facilities, the history of the industry has demonstrated that aquaculture is viable in Texas and that a conservative regulatory approach is warranted in combination with a fundamentally adaptive management approach (Baker 1997, Ray et al. 1998). To date, the industry has done an excellent job of coordinating with the regulatory and conservation communities to develop best management plans and strategies (GMP 1999). In 1998, the following management response was established for any future outbreaks of either WSSV or YHV (GMP 1999):

- Quarantine facility and contact Texas Parks and Wildlife Department (TPWD) immediately.
- Permit holders must send specimens to the Texas Veterinary Medical Diagnostic Laboratory for testing.
- Conduct weekly pond-side clinical testing of all ponds and report findings to TPWD.
- Remove dead shrimp along the edges of the pond and bury or incinerate.
- Permit holders must make effort to drive birds away from infected ponds.
- Harvest affected ponds as soon as possible.
- Retain all harvest water on the premises until approved by TPWD for disposal.
- Infected shrimp of marketable size must be sent to a processor that disposes of the wastewater and by-products in a manner that eliminates vectors for virus transmission.
- Harvest non-infected ponds as soon as possible or manage in a highly protective manner as described in an approved management plan.

Currently, there are 11 major coastal permits for exotic species of shrimp, 1 proposed coastal permit, 2 permits for inland facilities and 4 permits for research facilities (GMP 1999). Pacific white shrimp (*Litopenaeus vannamei*) is the only exotic shrimp species allowed for open mariculture systems. Blue shrimp (*Penaeus stylirostris*) are allowed in closed aquaculture systems outside an exclusion zone.

Specifics on the Shrimp Virus Issue in Florida

Aquaculture is Florida's most diverse agribusiness. Over 800 aquaculturists produce the greatest variety of aquatic species of any state in the nation (FDACS 2000). The State of Florida operates an annual certification program for aquaculture operations. There are eight certified facilities to raise marine shrimp, and of these eight facilities, four currently possess and culture marine shrimp (Zajicek, pers. comm.). The shrimp species cultured at these facilities is the exotic Pacific white shrimp (*Litopenaeus vannamei*). These facilities are not located in coastal areas, with the exception of one large shrimp hatchery on Summerland Key. This facility, which imports brood stock from Honduras, was subject to past outbreaks of TSV and IHNV, but

successfully eliminated the viruses by draining, drying, and disinfecting the facility (Treece, pers. comm.). More recently, no exotic shrimp viruses have been detected at any aquaculture facilities or in wild shrimp populations in Florida waters (three miles seaward on the Atlantic Ocean coast and nine miles seaward on the Gulf of Mexico coast) (Zajicek, pers. comm.).

Specifics on the Shrimp Virus Issue in Alabama, Louisiana, and Mississippi

Alabama, Louisiana, and Mississippi do not have any coastal shrimp farms, and do not conduct any regular monitoring for exotic shrimp viruses in coastal areas. Tom Van Devender, Mississippi Department of Marine Resources (MDMR), summarized the shrimp virus issue in Mississippi as follows (excerpted from Van Devender 2000):

Other than controlled research activities on shrimp viruses carried out at the Gulf Coast Research Laboratory, the State of Mississippi has no penaeid shrimp mariculture operations. While some live bait shrimp camps may capture live shrimp in one bay system, transport them either by boat or truck to open seawater systems and hold the shrimp for a few days (usually less), these activities hardly can be considered mariculture, and disease outbreaks among these wild stocks, even though held for a short time in crowded bait tanks, has not been reported.

Pounds of shrimp processed by local dealers exceed pounds landed in Mississippi several times over. Shrimp are brought in from other Gulf States and also imported from a number of foreign suppliers. The possibility of viruses from these imports being discharged with peeling machine process water into local bays and infecting wild stock does exist, but has not been documented. Apparently neither has the presence of viruses introduced or evident in wild stocks been described or enumerated. One of the fundamental data gaps to be addressed in any impact assessment is the identification of viruses and their distribution in Mississippi's native shrimp stocks.

5.2 Shrimp Virus Sources and Pathways

Section 5.2 was excerpted from JSA 1997.

Critical to evaluating the risks of shrimp viruses is understanding potential sources and pathways of virus. This section provides a discussion of the two primary virus sources – shrimp aquaculture and processing facilities. The Shrimp Virus Workgroup (SVW) of the Joint Subcommittee on Aquaculture considered these two sources as those with the greatest potential to introduce viral diseases into wild penaeid shrimp populations. This section also includes several other potential sources and pathways that were considered less critical by the SVW.

Aquaculture

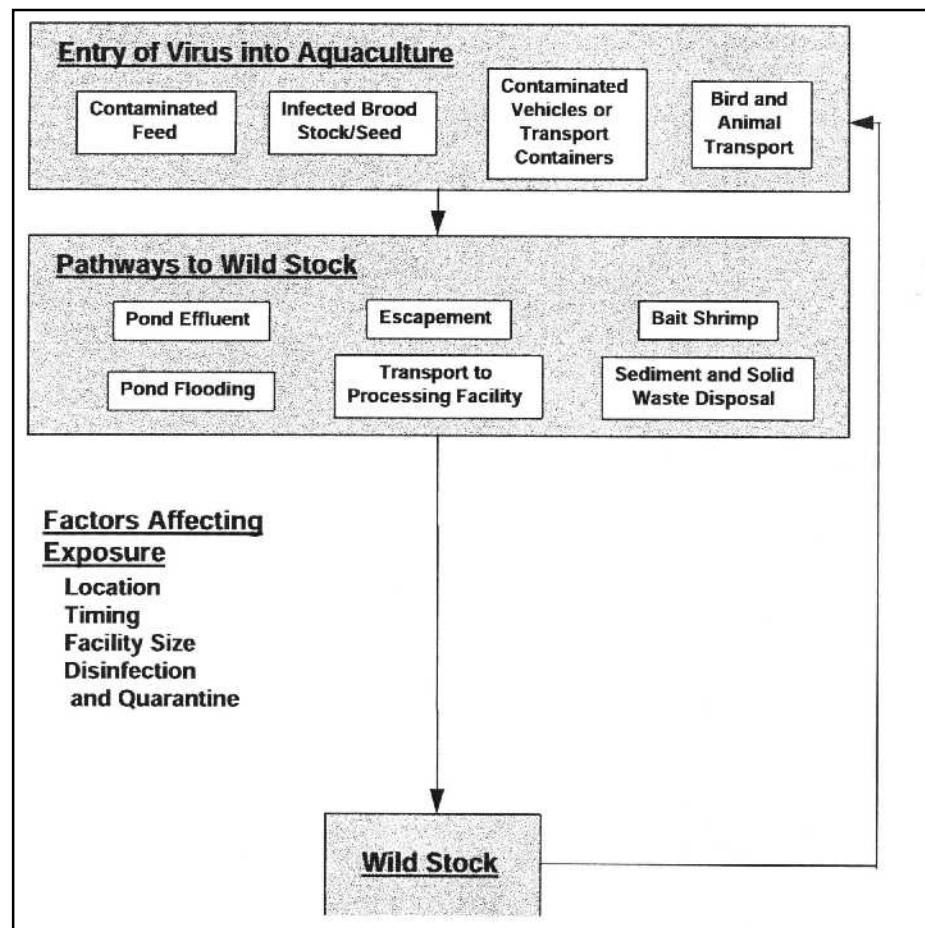
Entry of Viruses into Aquaculture Facilities

Although there are few outbreaks with confirmed sources, there exist several ways in which viruses may enter aquaculture facilities: (1) infected broodstock/seed; (2) transfer by birds (i.e., by seagulls via feces); (3) transfer by non-shrimp animal species (e.g., crabs, crayfish, squid,

other crustaceans, amphipods, isopods) as either carriers or transmitters; (4) contaminated feed; and (5) contaminated vehicles or transport containers (Figure 4).

For those viral outbreaks in Texas in 1995, it was speculated that viruses might have been transferred by birds to the affected aquaculture facilities. Though never confirmed, nearby shrimp packing plants, major importers and re-processors of large quantities of shrimp from Asia, were suspected as the ultimate source of the imported viruses. Reports that non-shrimp animal species may have been the source of some infections have been unsubstantiated. The 1996 TSV outbreaks in Texas apparently resulted from broodstock that were contaminated after they arrived at a hatchery, although the original source of broodstock infection is unknown. Farmers purchased infected seed from this facility, although recommended procedures direct farmers to avoid purchasing seed from a supplier having a recent history of disease.

Figure 4. Aquaculture as an Introduction Vector for Shrimp Viruses

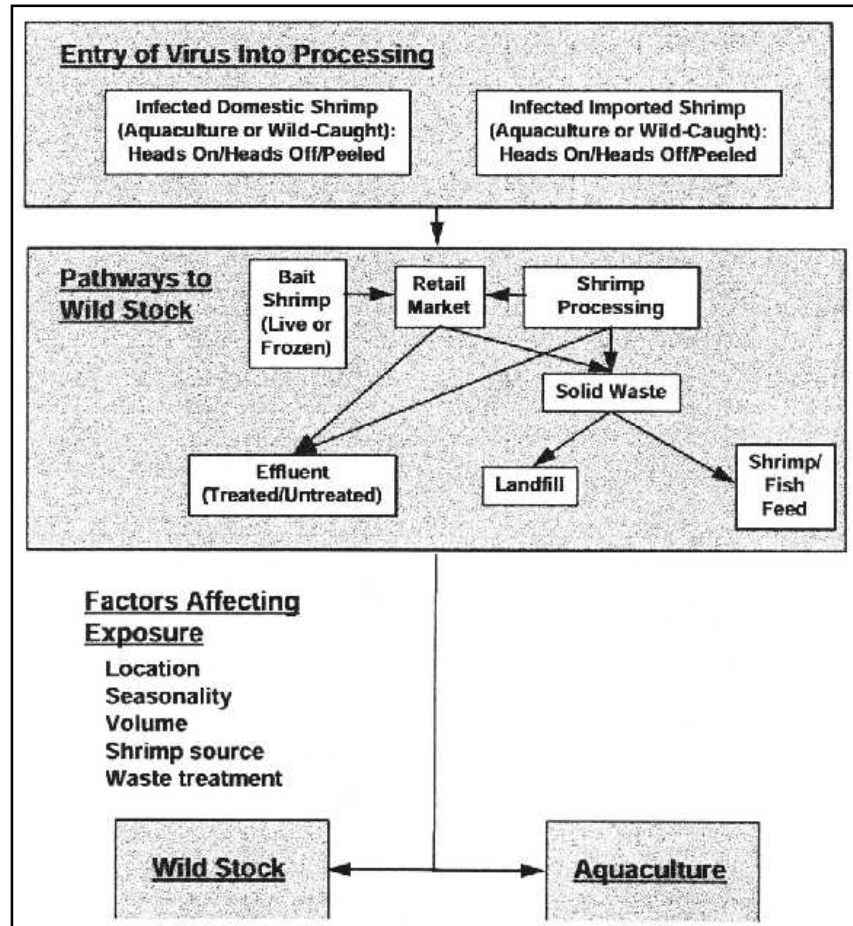


Pathways to Wild Stock

Native shrimp species may be exposed to viruses through a number of pathways from aquaculture, including: (1) pond effluents; (2) pond flooding; (3) escape of infected shrimp; (4) spills or losses during transport to shrimp processing facilities; (5) disposal of pond sediment or solid waste; and (6) infected bait shrimp (Figure 4). Wild shrimp may be most susceptible to

these exposures during certain time periods. Wild penaeid populations are most dense during immigration of postlarvae (e.g., usually spring and early summer) and immigration of juveniles (e.g., late summer into fall). In addition to these spatial and temporal relationships, other important factors in assessing potential exposures to native shrimp species include the volume of effluent discharged from shrimp farms and processors, as well as disinfection and quarantine procedures used in these facilities. Infected wild shrimp may contaminate aquaculture stocks through the use of infected wild broodstock and postlarvae or from contaminated materials entrained in local water supplies.

Figure 5. Processing as an Introduction Vector for Shrimp Viruses



Shrimp Processing

Entry of Viruses into Processing

Shrimp viruses enter processing in two ways: infected domestic shrimp (aquaculture or wild-caught) and infected imported shrimp (Figure 5). Currently, there are over 60 countries exporting both pond-raised and wild shrimp to the U.S. Over 50 percent of the shrimp processed in the U.S. is imported from Thailand, India, and numerous other countries where viral diseases are a major problem. Some countries harvest shrimp during the early stages of a disease outbreak in order to minimize disease effects on cultured shrimp yield. This strategy effectively

avoids high mortality and catastrophic economic losses in those countries, but increases the likelihood that shrimp imported into the U.S. will be contaminated with viable virus particles. In fact, virus-infected shrimp have been identified in retail stores in the U.S. Thus, importation of infected shrimp for processing by the U.S. shrimp industry significantly increases the potential for introduction of pathogenic viruses into coastal waters adjacent to the processing plants.

Pathways to Wild Stock

Infected shrimp processed in the U.S. may infect wild shrimp through the following pathways: (1) solid waste; (2) effluents (treated or untreated); (3) bait shrimp (live or frozen); and (4) infected material from processing used in shrimp and fish feed (Figure 5). For example, solid wastes from processing facilities are often processed into meal at low temperature (i.e., not sufficient to inactivate pathogenic viruses). This meal is added as a protein source to shrimp feeds. If this feed is used for animals in aquaculture, and wastewater containing pathogenic viruses from culture facilities is discharged into local receiving waters, local wild shrimp stocks may be at risk from this pathway. Important factors to consider when evaluating risks to native shrimp and aquaculture populations include facility location, seasonal patterns, varying volumes of effluent discharges, the source of potentially contaminated shrimp for processing, and waste treatment procedures.

Other Sources and Pathways

Live or Frozen Bait Shrimp

Pathogenic viruses may be found in infected bait shrimp that could contaminate wild stocks through use in recreational and subsistence fishing. The bait shrimp industry is integral to the U.S. shrimp fishery, and it supports a large and economically-important sportfishing industry in the Gulf of Mexico region. Because the demand for bait shrimp is high, especially when local shrimp supplies are limited, many bait shrimpers haul live shrimp among different bays within a state or across state lines. At certain times of the year, the demand for bait shrimp has been so great that suppliers to the recreational fishery have had to depend on imported shrimp to meet the demand. When contaminated bait shrimp are discarded, wild stocks feeding on these discards could be vulnerable to infection, especially during the spring and summer when postlarval shrimp are migrating into the coastal nursery areas.

Ballast Water

The transport of live shrimp in ballast water is well documented. It is estimated that 25 or more species of shrimp have been released to U.S. surface waters through ship ballast. The introduction of pathogenic viruses may be possible with the establishment of these new species. However, virus introduction to wild stock may result even if exotic shrimp species originating in ballast water do not become established (e.g., diseased, dead, or dying shrimp discharged from ballast may be eaten by or come in contact with wild crustaceans). Ballast water can include a mix of crustaceans (e.g., crab larvae, amphipods, and isopods), and the possibility of viral transmission from one crustacean species to another may be amplified under these conditions.

Research and Public Display

Pathogenic viruses may be unintentionally released in association with wastes, feed, or organisms from research activities at public agencies, universities, or large public aquaria, or by

discarded ornamental cultures of shrimp or other crustaceans. Many of these facilities are located in coastal areas in proximity to habitat for wild shrimp populations. Proper quarantine or disinfection procedures for new or exotic organisms (i.e., especially those known to carry pathogens) are critical for preventing the release of pathogenic organisms, but the extent of these procedures varies greatly among research and display facilities.

Non-Shrimp Translocated Animals

Animals other than shrimp may carry viruses that could infect shrimp populations. Potential pathways for viral entry include international, national, or regional transport of infected live animals, bait, or feed materials. Important factors affecting exposure to wild shrimp include location, seasonality, the number of animals, and the proximity of their habitat relative to wild shrimp. All but the most basic information is unavailable for evaluating the potential exposures these animals represent to wild shrimp.

Natural Spread

While anthropogenic pathways for the introduction of pathogenic viruses to wild shrimp are the primary concern, it is possible that the spread of a virus could be enhanced by natural processes. Examples include movements by large-scale water currents, hurricane or flood events, and translocation by birds or other animals. Little information is available on this potential pathway for exposure to pathogenic shrimp viruses.

Other

Two other sources are considered less important than the preceding sources – fishing vessels and intentional introductions. When fishing vessels based in U.S. ports return from foreign waters, their nets and other equipment may be contaminated with organisms or materials that harbor pathogenic shrimp viruses. While intentional introduction of a virus is possible, it is not considered likely, and it would be difficult if not impossible to predict or control.

5.3 Management Framework Related to Shrimp Viruses

Federal Level

Because pathogenic shrimp viruses have the potential to be spread through interstate commerce, the federal government has regulatory authority in this area. Numerous federal agencies have statutory authorities, roles, and overlapping responsibilities for regulating the importation and movement of aquatic animals and products in commerce (see Section 7.0). Although human health and food safety are clearly provided for under existing federal statutes, the health of U.S. domestic shrimp, other crustaceans, and other susceptible “wild” animals may not be adequately protected from diseases that may result from the importation of aquatic animals or animal products. Under the Lacey Act, importation of plants or animals that are considered injurious to humans, to the interests of agriculture, horticulture, forestry, or to the fisheries and wildlife resources of the U.S. is prohibited; however, current provisions do not address shrimp viruses.

To prevent future threats to aquaculture, indigenous species, and aquatic ecosystems, federal agencies need to better define and coordinate their roles in a number of areas, including importation, interstate movement, release of live animals, and waste management (JSA 1997). A variety of federal statutes give several different agencies responsibilities for managing risks associated with shrimp viruses; however, these statutes do not specifically reference shrimp pathogens. Federal agencies that have authority include the U.S. Fish and Wildlife Service, National Marine Fisheries Service, Animal and Plant Health Inspection Service, and U.S. Environmental Protection Agency.

Joint Subcommittee on Aquaculture (JSA)

The JSA is a federal interagency advisory group formed under the auspices of the President's Office of Science and Technology Policy. The JSA formed a Shrimp Virus Work Group in 1996 in response to the growing threat to shrimp aquaculture and concerns for possible effects on wild shrimp populations from shrimp viruses. The primary task of the Work Group is the development of an interagency strategy to address the shrimp virus issue. As a first step, the Work Group identified existing authorities among federal agencies, as well as research underway on shrimp viruses, their mode of transmission, and potential for introduction into U.S. waters (JSA 1997). In addition, the following actions are being pursued: (1) support information exchange and education; (2) develop a risk assessment; and (3) determine actions needed by the U.S. to prevent introductions.

U.S. Marine Shrimp Farming Program

Funded by the U.S. Department of Agriculture, the Cooperative State Research, Education, and Extension Service, and other cooperating institutions, this program operates a Nucleus Breeding Center and quarantine centers, and supplies specified pathogen free (SPF) shrimp stocks to the U.S. shrimp aquaculture industry.

Regional Level

The GMP and its federal agency partners have focused considerable effort on the exotic shrimp virus issue in the Gulf of Mexico. In the summer of 1996, a joint U.S./ Mexico shrimp virus workshop was held by the Joint Subcommittee on Aquaculture Shrimp Virus Work Group (co-sponsored by the National Atmospheric and Oceanic Administration (NOAA), the U.S. Department of Agriculture, U.S. Fish and Wildlife Service, and USEPA). The purpose of the workshop was to compile knowledge about shrimp virus status, impact, and threats to the shrimp culture industry, as well as to wild shrimp populations. Recommendations resulting from the workshop included an assessment of disease and financial risks associated with the introduction and spread of shrimp viruses in the wild and to shrimp farms (Kumpf et al. 1999). The second Gulf-wide effort, in February 1998, was a NOAA/USEPA workshop organized to address the development and implementation of specific management strategies dealing with exotic shrimp viruses, ballast water pathways, and potential introduced species (Kumpf et al. 1999).

State Level: Florida

This section was adapted from information available at the Division of Aquaculture, Florida Department of Agriculture and Consumer Services website (FDACS 2000).

During 1984 the Florida Legislature passed the Florida Aquaculture Policy Act (FAPA) to create a governmental framework conducive to the orderly growth of aquaculture. FAPA, codified in Chapter 597, Florida Statutes, has been amended almost every year since its passage to refine the working relationship between the industry and state government. FAPA directs the Department of Agriculture and Consumer Services (FDACS) to carry out a variety of responsibilities. An important component of FAPA is a farmer advisory committee, the Aquaculture Review Council (ARC). The ARC provides guidance to the Commissioner of Agriculture and critical input on the annual development of the Florida Aquaculture Plan. The Act also requires all Florida aquaculturists to acquire a Certificate of Registration and abide by a set of Best Management Practices (BMPs) (outlined in Rule 5L-3). The FDACS is responsible for compliance with these BMPs and conducts annual compliance inspections of farm facilities. In the event of a farmer and agency conflict, FAPA directs the FDACS to provide assistance in the form of an Aquaculture Ombudsman to intercede on their behalf.

Chapter 597, Florida Statutes, states that “any person engaging in aquaculture in the State of Florida must be certified by the department.” The purpose of the Aquaculture Certification Program is to identify aquaculture producers and aquacultural products, and to implement appropriate BMPs at these aquaculture facilities. The appropriate Aquaculture Certification number must be on all aquaculture products from harvest to point of sale. An Aquaculture Certificate also exempts aquafarmers from certain requirements of wild-harvested species, offers tax advantages, and reduces the number of permits required from other regulatory agencies.

State Level: Mississippi

Prevention of nonindigenous shrimp virus introductions could only be addressed through a broad interpretation of Mississippi’s Aquaculture Act (Mississippi Code Annotated §79-22-9 (1972 & Supp. 1999)), passed in 1988 (Van Devender 2000). Most provisions of the act, including issuance of aquaculture cultivation and marketing permits, are administered by the Mississippi Department of Agriculture and Commerce (MDAC). Cultivation permits for any nonindigenous species are required. The Aquaculture Task Force (ATF), established in the act, is charged with advising the MDAC in its permit issuance responsibilities. The Mississippi Department of Marine Resources (MDMR) is one member of the ATF, and Section 79-22-15(4), Mississippi Code of 1972 states:

“The Department of Wildlife, Fisheries and Parks [more suitably MDMR (Van Devender 2000)] may promulgate regulations which specify criteria to protect marine resources and to prevent the release of undesirable species from an aquaculture facility into the environment.”

Mississippi has a list of prohibited species determined by the ATF to be detrimental to Mississippi's native resources, and their release into state waters is forbidden. Further aquaculture regulations require nonindigenous species to be cultured with a filter system to

prevent passage of eggs, larvae, juveniles or adults. However, neither the prohibited list nor filter requirements affect the possibility of viral releases. Prevention of viruses released from non-aquaculture activities would fall into a gray area of authority (Van Devender 2000). Tom Van Devender, MDMR, concludes:

“Only after we can say with some degree of certainty which viruses are endemic, which may appear on an irregular periodic basis like the various influenza viruses, or which might be genuinely entirely new and introduced by man's activities, and then only after some analysis of the effects these viruses have on shrimp and all other important marine species can we begin to craft meaningful, enforceable regulations.” (Van Devender 2000).

State Level: Texas

*The following sub-section was adapted from information provided
by Larry McKinney, Texas Parks and Wildlife Department, in Battelle (1999)*

In 1975, the Texas Legislature gave the Texas Parks and Wildlife Department (TPWD) authority to prohibit the introduction of nonindigenous fish species into Texas waters. The Texas Parks and Wildlife Commission (TPWC) began to actively recruit the mariculture industry in 1986, and in 1987, the Texas Legislature passed a law allowing an exemption from water rights permitting for mariculture facilities. The Fish Farming Act of 1989 transferred most aquaculture responsibilities from TPWD to the Texas Department of Agriculture (TDA). TDA responsibilities include: (1) promote fish farming products; (2) license and regulate facilities; (3) provide technical assistance; (4) provide coordination for university and government entities; and (5) develop and expand the industry. TPWD responsibilities include: (1) adopt rules to regulate aquaculture of exotic species; (2) publish a list of prohibited exotic species; (3) prohibit the release of exotic species; and (4) enforce exotic species rules (Texas Agricultural Code § 134.001).

In addition to regulating exotic species for aquaculture use, TPWD is the state agency responsible for protecting fish and wildlife resources and managing wild shrimp populations. The TPWD management strategy attempts to be responsive to both the harvest and aquaculture industries, as well as to meet mandated resource protection responsibilities. Key elements of this strategy include allowable exotic species, disease management, native species management, and coordinated permitting. Specific policies and procedures include:

- Allowable exotic shrimp species include Pacific white shrimp (*Litopenaeus vannamei*) for open mariculture systems, and blue shrimp (*Penaeus stylirostris*) in closed systems outside an exclusion zone.
- TPWD has worked with industry to develop management responses for IHHNV, TSV, WSSV, and YHV outbreaks.
- TPWD initially supported the use of native shrimp, however staff are no longer convinced that use of native shrimp is the best option.
- The Texas Natural Resource Conservation Commission (TNRCC) and TPWD coordinate mariculture regulation through a Memorandum of Understanding. TPWD will not issue an

Exotic Species Permit until a TNRCC discharge permit is obtained; TPWD has a formal role in the TNRCC permitting process.

The Fish Farming Act mandated that an Aquaculture Executive Committee (AEC) adopt rules for fish farming, advise TDA to suspend licenses for violations, and employ an aquaculture liaison to coordinate activities among the entities. However, the AEC is unable to carry out its directives due to budgetary constraints. Senate Bill 977 (1991) amended the Fish Farming Act by: (1) abolishing the aquaculture liaison position; (2) requiring the AEC to assist applicants seeking aquaculture permits; (3) requiring the AEC to coordinate the issuance of permits; (4) requiring the AEC to compile a strategic plan biennially; (5) requiring each member of the AEC to appoint a staff member as aquaculture coordinator; and (6) creating an industry advisory committee.

In 1995, TPWD and TNRCC enhanced their regulations to better address disease and discharge issues pertaining to mariculture facilities along the Texas coast. The goal of the resulting Aquatic Exotic Species Program, implemented in March 1995, is to prevent the introduction of nonindigenous aquatic fish, shellfish, and aquatic plants to the public waters of the State. Components included:

- **Emergency Plans:** Require the submission of a plan for all applicants within an exclusion zone, describe methods used to prevent release or escapement in the event of a natural catastrophe, and replace the rule to destroy exotic species with an approved biocide.
- **Research Permits:** Reduce the possibility for exotic species escaping and impacting the marine environment and permit new exotic marine species research outside the exclusion zone. The permit also requires research facilities within the exclusion zone to: (1) be fully quarantined; (2) have a closed life support system; (3) have an effluent treatment system designed to prevent escape of animals and release of disease-laden effluent; (4) have an approved emergency plan; (5) have secured facilities; (6) have an approved disposal method for exotic species; (7) agree not to promote the use of unapproved exotic species; and (8) have an approved research proposal.
- **Health Certification:** Required for all exotic shellfish possessed by individuals conducting research or displaying animals in public aquaria.
- **Screening Requirement:** Requires (1) a permanent screen (strong enough to prevent a “blowout”) in front of the final discharge pipe in the harvest structure and (2) a screen over the end of the discharge pipe of facilities discharging into public waters.

In November 1996, the purchase of live Pacific white shrimp was allowed by licensed retail or wholesale fish dealers without a permit if their place of business is located outside the exclusion zone. In January 1997, Exotic Species and Discharge Permits required (1) new applicants to obtain a discharge permit or an exemption from TNRCC prior to applying for an Exotic Species Permit and (2) existing Exotic Species Permit holders to demonstrate they possess or have applied for a TNRCC discharge permit or exemption. The following disease management components were added to the Aquatic Exotic Species Program in April 1998: (1) definitions and new rules concerning exotic and native shellfish; (2) a weekly clinical analysis checklist; and (3) a choice for permit holders between requesting an inspection from an approved

examiner or submitting samples to a laboratory for disease analysis as a result of manifestation of disease or before discharging.

Aquaculture Industry

A voluntary SPF broodstock and shrimp seed program is used in the U.S. to help prevent contamination of commercial aquaculture operations by pathogenic viruses. High Health facilities are an important part of the SPF-based industry – producing seed for growout with a documented history of pathogen surveillance. Other elements of disease prevention in the industry include farm biosecurity practices and quick response to disease outbreaks.

6.0 Gulfwide Issues Addressed by the ISFT: Ballast Water

"Every minute, 40,000 gallons of foreign ballast water is dumped into U.S. harbors."

James Baker, Under Secretary, U.S. Dept. of Commerce (ISC 2000)

"Transport of entire coastal planktonic assemblages across oceanic barriers to similar habitats renders bays, estuaries, and inland water among the most threatened ecosystems in the world."

Carlton and Geller 2000, of international ballast water exchange

To support Gulf-wide coordination and communication of invasive species issues, the GMP sponsors a multi-stakeholder Invasive Species Focus Team (ISFT). While the Focus Team serves as a venue for all regional, state, and local invasive species problems, the ISFT is currently focused on three issues of Gulfwide importance: shrimp viruses, ballast water as an introduction vector, and the prevention of new introductions of invasive species. To date, the majority of the Focus Team's efforts have been concentrated on the first two issues. Section 6.0 provides a summary of the ballast water issue for the Gulf of Mexico region.

6.1 Overview of the Ballast Water Issue

Fundamental to world trade, ships have moved across the oceans for centuries and currently transport approximately 80 percent of the world's commodities (NRC 1996). Ballast, normally in the form of water, is an integral part of the safe operation of ships under a wide range of conditions and loads. The uptake, transport, and subsequent discharge of water and sediment from ship ballast tanks can disperse aquatic organisms – including jellyfish, crabs, clams, fish, snails, bacteria, and viruses. Research has confirmed that plants, animals, and pathogens can live and grow over a long period in ballast tanks and cargo holds (Smith et al. 1996). It has been estimated that more than 3,000 species of animals and plants are transported daily around the world in ballast water (NRC 1996). While the introduction of bacteria and viruses through ballast water is a growing concern (Associated Press 2000), its potential remains virtually unexplored by scientists (Ruiz et al. 2000). The potential for entire coastal planktonic assemblages to be introduced by international ballast water transfers, make bays, estuaries, and inland waters some of the most vulnerable ecosystems in the world (Carlton and Geller 1993).

The effects from some introductions have resulted in expensive remedial actions and a broad range of adverse ecological repercussions resulting in government, public, and scientific attention on the role of shipping as a dispersal vector for nonindigenous aquatic organisms (NRC 1996). Ports, states, and nations and the international community, under various international, national, regional, and local programs, are evaluating the potential impacts of the introductions and conducting scientific research to support the evaluation of appropriate management strategies and actions to control introductions from ballast water.

Appropriate management and control strategies designed to reduce the threat of nonindigenous species introductions must effectively address a complex diversity of multiple source and discharge environment pairings, and organism diversity in the ballast tanks. The task of developing control methods is complicated further by the need to address shipboard safety, technical feasibility, cost effectiveness, and practicality.

Because of the lack of alternative ballast water control strategies, open-ocean exchange – exchanging ballast water loaded in port or in inshore waters with ocean water during passage between ports of call – is the only control option being implemented for reducing the risk of introduction. This method is considered effective because most freshwater and estuarine organisms cannot survive when discharged into the open ocean environment and vice versa.

However, few studies have been conducted to determine the effectiveness of open-ocean exchange. A recent evaluation of the efficiency of ballast water exchange practices and degree of ship compliance concluded that although thousands of ships routinely conduct open-ocean exchanges, very few studies have directly measured the efficacy of the procedure, and more research on both reballasting and dilution procedures is needed on a wider range on ship types (Hay and Tanis 1998). Further, because of the complex biological diversity within the tanks, there is some question whether open-ocean exchange facilitates the survival of some organisms that would otherwise die off prior to port arrival. These uncertainties combined with the fact that open-ocean exchange can compromise vessel safety and can be costly, particularly when exchange time exceeds voyage time, has led to the conclusion that open-ocean exchange is a short-term ballast water management approach.

This conclusion has prompted research and investigations into other control options. Control options being investigated internationally include avoiding ballasting if water is likely to contain unwanted organisms (e.g., in areas of sewage discharge or high sediment loads) and shipboard and shore-based treatment of ballast water. A ballast water management plan developed in conjunction with the ship cargo plan could provide flexibility for meeting contingencies and avoiding ballasting in certain locations. However, without solid criteria and supporting science, it is difficult to determine which ports pose highest risk. As a result, development of risk assessment frameworks are now being recommended to assist managers in targeting their resources and efforts on those ports of origin, vessels, and particular species that pose the most threat.

Current research has focused on ballast water treatment options. Shore-based treatment of ballast may have some advantages, but centralized handling and treatment of such large volumes of water poses many economic and infrastructure challenges including, increased port

congestion, lack of available land for treatment facilities, and delays in ship schedules. Although shipboard treatment also poses considerable challenges (e.g., space and energy limitations, shipboard safety), it currently provides the most flexibility in managing ballast water.

Ballast Water Treatment Options

In an evaluation of ten major categories of candidate shipboard treatment technologies, the National Research Council (NRC) identified several promising approaches including physical separation methods, the addition of low concentrations of biocides, and thermal treatment (NRC 1996). Numerous research projects are underway that attempt to quantify the effectiveness of a wide variety of shipboard and shore-based treatment technologies (Table 10). In addition to those listed in Table 10, several foreign countries have shipboard treatment research underway (Cangelosi, 1999):

- Singapore: Repetitive Bench-Scale Trials of Various Technologies
- Norway: Biological Efficacy of UV
- Germany: Efficacy of Various Chemical Treatments
- Japan: Electrolytic Treatment
- Brazil: Ballast Tank Modifications to Facilitate BWE
- Canada: Thermal Treatment
- Australia: Decision Support System (Hazard Assessment)

Table 12. Status of Ballast Water Treatment Technology Research Projects

Technology	Complete	Underway	Pending
Waste Engine Heat	1996 (Australia)		
Backwash Filtration	1997-98 (GLBTDP)		
Gluteraldehyde		1997-99 (UM)	
Peracetic Acid		1998-2000 (SUNY)	
Shoreside Treatment		1998-2000 (SFBI)	
Cyclonic Separation/UV		1998-2000 (Velox)	
Excimer Ultraviolet		1998-2001 (Sea Grant)	
Ultraviolet (various)			2000 (GLBTDP)
Full-Scale Design and Installation Plan			2000 (GLBTDP)
Ultrasonics/Ozone			1999-2001 (Sea Grant)
Ultrasonics			1999-2001 (Sea Grant)
Electrically-Generated Ozone			1999-2001 (Sea Grant)
Juglone			1999-2001 (Sea Grant)
EVT: Voraxial Separator			2000-2002 (UMCBL)

GLBTDP = Great Lakes Ballast Technology Demonstration Project; UM = University of Michigan; UMCBL = University of Maryland Chesapeake Biological Laboratory; SFBI = San Francisco Bay Initiative; SUNY = University of New York Stonybrook.

Source: Cangelosi 1999 and BusinessWire 2000

Another evaluation of three ballast water treatment technologies – ultraviolet (UV) radiation and thermal and acoustic techniques – concluded that ultraviolet radiation is currently the best suited technology for secondary treatment of ballast water, because it is well developed, has many vendors for producing equipment for a variety of applications, and shows the best potential for shipboard trials (Battelle 1998). Since that evaluation was completed, four treatment technologies have been developed and are being tested on vessels, including a combined filtration and UV treatment system developed by OptiMarin, a Norwegian company, in conjunction with Hyde Marine, Inc. This combined system was installed aboard the Princess Cruise Lines *Regal Princess* during the late spring of 2000. Performance data is not available at this writing, and it is unknown whether the technology can be effectively and efficiently applied as a treatment method for the trade shipping industry, which often requires more frequent ballasting operations per voyage. The Battelle (1998) evaluation also indicated that ultrasonics technology shows promise for application to ballast water treatment, but more research is needed to determine if the technology is suitable for large-scale volumes and high flows. Many of the technologies currently under investigation could prove effective in the future, and it is unlikely that one treatment technology or control strategy will suffice for all situations.

6.2 The Ballast Water Issue in the Gulf of Mexico Region

Shipping and Ballast Water in the Gulf of Mexico Region

Ranked by tonnage, the Gulf of Mexico region is home to eight of the ten largest ports in the U.S. These include both coastal ports (e.g., Tampa, and Galveston) and riverine ports (e.g., Mobile, Houston, New Orleans, and South Alabama). These ports move a large volume of international trade, including a high portion from the countries bordering the Gulf of Mexico and the Caribbean Sea. Two of the largest inland waterway systems, the Mississippi River system and the Tennessee-Tombigbee Waterway, flow through these ports and into the Gulf of Mexico. Most of the coastal and riverine ports are linked by the Gulf Intracoastal Waterway (GIWW).

Table 13. Distribution of Cargo, Vessel Types, and Ballast Water Exchange for Five Major Gulf of Mexico Ports

Port	Cargo (million tons)	Type Vessel	Ballast Water Exchange
Houston	149	78% Tankers	3.7 million metric tons (1 billion gallons/yr)
New Orleans	83	37% Tankers 36% General Cargo	21.8 million metric tons (5.8 billion gallons/yr)
Gulfport	2.0	74% General Cargo	17.8 thousand metric tons (47 million gallons/yr)
Mobile	50.8	70% Bulk Carriers	1.1 million metric tons (293 million gallons/yr)
Tampa	51.3	52% Bulk Carriers	2.1 million metric tons (543 million gallons/yr)

Source: Kumpf et al. (1999)

Collectively, a very large volume of cargo is shipped through the ports of the U.S. Gulf Coast. A study of five major ports in the Gulf of Mexico calculated estimates of 1996 ballast water releases based on cargo volume and ship type (Table 13). The largest volume of ballast discharged across these five ports is released by bulkers calling on the Ports of Lower Mississippi, followed by tankers in the Port of Houston, and general cargo in the Lower Mississippi (Battelle 1998).

Detailed ballast water information is now being collected under the National Ballast Water Survey. This survey is being conducted by the U.S. Coast Guard (USCG) to evaluate the level of ship compliance with the voluntary at-sea exchange guidelines for foreign vessel arrivals. Upon entry into U.S. ports, foreign vessels are required to submit a ballast water reporting form (Appendix C) indicating whether an exchange has been conducted, and the volume and location of exchange. All information reported on the ballast water reporting form is recorded in the National Ballast Water Information Clearinghouse (NBWIC), operated and maintained by the Smithsonian Environmental Research Center (SERC).

NBWIC data relevant to arrivals, ballast water discharge volumes, and vessel origin is summarized by USCG and is available via the Internet (<http://invasions.si.edu/whats.htm>). The data summary for all port zones completely included in the Gulf of Mexico region is shown in Table 14: port zone abbreviations in Table 14 can be cross-reference with the geographical coverage shown in the map provided in Figure 6. The MIAMS port zone was excluded from data summary provided in Table 14 as it encompasses areas beyond the Gulf of Mexico region. Though only a summary of the information collected for the ballast water reporting forms is available via the Internet, all fields on the ballast water reporting form are recorded in the central database maintained by SERC. SERC will provide this dataset, organized by state, upon formal written request (Miller, pers. comm.).

The data presented in Table 14 is considered draft, but some general trends and conclusions can be drawn responsibly. For example, the data show that of the 1831 total vessels reporting, more than half reported that some exchange was conducted. More than half, 63 percent, of the approximate 4 million gallons of ballast water from all vessels was exchanged.

The data also show that a large proportion of vessels reporting originate from the Caribbean and South and Central America. The summary data available through the NBIWC does not provide sufficient detail to allow an analysis of the proportion of ballast water discharge, after exchange, to the source region. However, transit time for traveling the major shipping routes (Figure 7) is often not long enough to conduct full exchange, and there are few areas along these routes that meet the criteria for open-ocean exchange. Further review of a more detailed dataset from the NBWIC could provide the needed data to assess exchanged discharge volumes in Gulf ports relative to ship sources.

Table 14. National Ballast Water Clearinghouse Data^a Relevant to the Gulf of Mexico Region

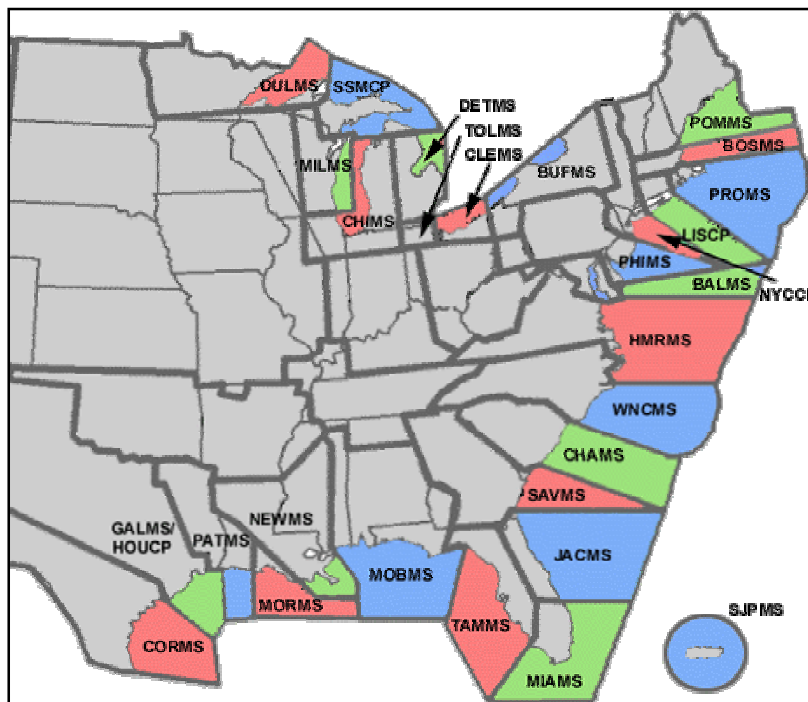
LOCATION REPORTING FORMS ARRIVALS/DISCHARGE							VESSEL TYPES						SOURCE REGIONS BY CONTINENT OR REGION										
U.S. Coast Guard District	Captain of the Port Zone ^b	Total No. Vessels Reporting	Arrivals Discharging	Arrivals Discharging with Exchange	Discharge Volume following Exchange	Total Discharge Volume	Other/Unknown	Tanker	Passenger	General Cargo	Container	Bulker	Africa	Asia	Atlantic Islands	Australia	Caribbean	Central America	Europe	Middle East	North America ^c	Pacific Islands	South America
7	TAMMS	270	94	32	287901	392379	89	48	61	21	4	39	6	6	0	1	50	59	17	2	88	0	30
8	CORMS	164	50	25	176544	430146	33	85	0	1	4	36	8	3	0	0	8	2	14	2	65	0	59
8	HOUCP	628	223	128	492101	1092323	97	306	0	9	114	70	20	16	0	1	104	62	51	14	248	0	90
8	MOBMS	118	39	22	135172	184334	43	16	1	7	16	29	6	10	0	1	6	23	7	4	31	0	21
8	NEWMS	546	206	128	1200710	1527240	54	186	103	13	38	125	26	22	0	0	41	23	86	30	212	0	82
8	PATMS	105	32	21	215962	324486	14	69	0	2	4	12	4	2	0	0	12	4	8	7	49	0	16
Total		1831	644	356	2508390	3950908	330	710	165	53	180	311	70	59	0	3	221	173	183	59	693	0	298

Source: SERC, <http://invasions.si.edu/whats.html>

^a Data collected in the period between July 1, 1999 and March 31, 2000.

^b There was no data reported for the MORMS port zone in the SERC data summary.

^c North American data includes vessels originating from Mexico and Canada. A request was made to SERC to provide the vessels information for each country. However, there was insufficient time to accommodate the request by the time of this submission. Data will be available by the end of September 2000.

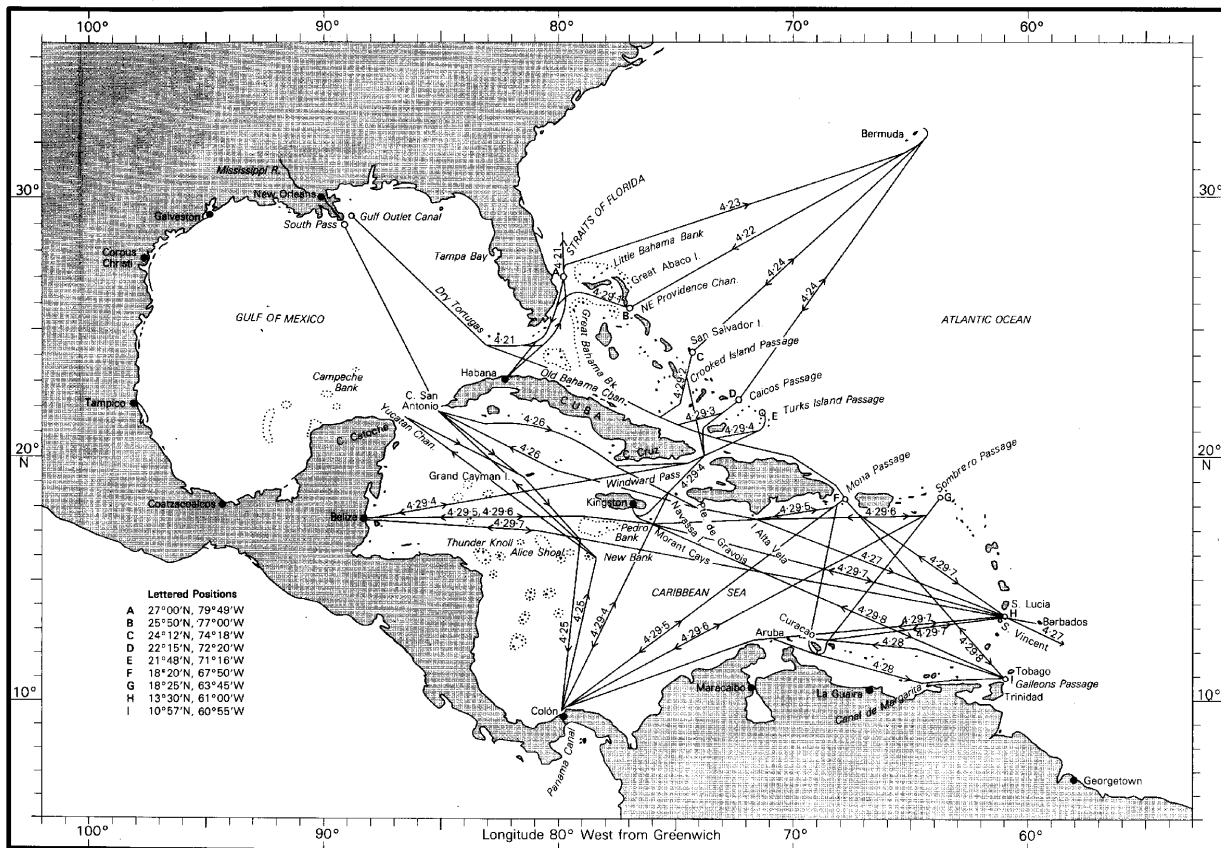
Figure 6. Port Zone Boundaries of National Ballast Water Clearinghouse

Source: SERC, <http://invasions.si.edu/whats.htm>

Assessing the Risk of Ballast Water as an Introduction Vector in the Gulf of Mexico Region

Many factors affect the likelihood of nonindigenous species introductions from ballast water and the survivability of the newly introduced organisms. To clarify the vulnerability of ports within the Gulf of Mexico, a better understanding is needed of each port's potential to serve as a conduit for future invasions of nonindigenous species. One of the primary factors that should be considered is total volume of ballast discharged and total volume of ballast discharged after exchange. However, this factor alone can not be used to assess port vulnerability. Other factors that need to be considered in relation to one another and to ballasting operations and volumes discharged include: types and proportions of transport vessels and cargos; trade partners; origin of ballast; natural environment and port water quality compared to water quality of trade partners; and location of known pests and foulants in port (Barrett-O'Leary 1999). Data and information on shipping and ballasting operations can be obtained through the NBWIC and a more extensive analysis is recommended. Natural environmental and water quality data can only be obtained through research and field studies. Summarized below, is a discussion of these risk factors, which has been adapted from Barrett-O'Leary (1999) and discussed in context with the availability of NBWIC data.

Figure 7. Gulf of Mexico Shipping Routes



Source: Ministry of Defence (1987)

Tonnage and Ballast Water Discharge Volumes

The three ports handling the highest amount of export tonnage in the U.S. are all located along the Gulf of Mexico – the Port of South Louisiana, the Port of Houston (number one in terms of foreign tonnage), and the Port of New Orleans (Barrett-O’Leary 1999). Review of export statistics assist in determining which ports should be evaluated further because it indicates which ports are likely to be receiving the highest volume of ballast discharge. However, total volume of ballast water discharge is not the only factor to be considered.

With the initiation of the National Ballast Water Survey, the NBWIC now contains data on the volume of ballast water discharge, the total volume of ballast on board, and total ballast water capacity. Using data in Table 14, within the Gulf of Mexico region, the NEWMS port zone that includes Southern Louisiana receives the highest volume of ballast water discharge; second is the GALMS/HOUCP area containing the ports of Galveston and Houston. These statistics alone would suggest that the NEWMS port zone is a higher risk area for the receipt of introduced species. However, the proportion and total volume of ballast water discharged after exchange in the NEWMS port zone is actually higher than that of the GALMS/HOUCP zone, indicating that the GALMS/HOUCP is the area of greater risk. A more detailed evaluation on ballast discharge volumes with and without exchange should be conducted to assess trends over time to assist individual Gulf ports in assessing and unexchanged ballast discharge volumes.

Types and Proportions of Transport Vessels and Cargo

The risk to individual ports is related, first, to tonnage and ballast water discharge volumes, and second, to the ballast water exchange procedures associated with different vessel and cargo types. Of the known vessel types reporting (Table 14), the largest proportion of vessels arriving in all Gulf of Mexico ports are tankers (49 percent), followed by bulk carriers. Research suggests that bulk carriers exchange a large volume of ballast and thus, may be more likely to introduce nonindigenous species (Barrett-O’Leary 1999). Often bulkers carry a single commodity (e.g., ore, woodchips, etc.) that are loaded or unloaded in total at a particular port. Therefore, exporting vessels arrive in port fully ballasted and discharge full volumes while in port to take on cargo. In this situation, without any open-ocean exchange, the total volume of water and organisms discharged from the bulker would originate from the last port of call. There are times however, when bulkers load or unload cargo at a number of sequential ports before offloading the entire amount of cargo at a final destination port (Carlton et al. 1995). In these instances, similar to the ballasting operations of cargo or container ships, the ballast discharged at the final port is a mixture of water taken on in many different ports and may harbor organisms from several origins. Tankers tend to conduct ballasting operations in a similar manner to bulkers.

Container and general cargo vessels usually do not discharge the large volumes that bulkers and tankers do, however, they make faster, more direct voyages. This short transport pattern may provide better opportunities for plants and animals to live in ballast tanks, or even survive a short period in the saltwater environment following an open-ocean exchange (Barrett-O’Leary 1999). In most cases container ships partially load and unload cargo at many different ports, taking on and discharging partial volumes of ballast to compensate for the cargo distribution. As a result, container ships often carry ballast water from many different ports and depending upon

the loading and unloading pattern, ballast tanks can contain a homogenized mix of ballast water from several different ports (Carlton et al. 1995).

This information combined with the proportion of vessels types entering the Gulf of Mexico (Tables 13 and 14) suggests that more attention should be focused on bulk carriers and tankers. However, crucial data is lacking to make such determinations. More detailed data and information, by port, is needed on vessel types in conjunction with the volumes on ballast discharged with and without exchange to assess patterns and trends and to begin to assess and predict individual port risk. However, evaluation of these factors alone will not provide the necessary information for a full assessment. To fully understand the impacts and potential risk posed by ballast discharge, ballasting operations must be considered in context with the source of the ballast water to predict the likelihood of organism survivability in the receiving port.

Trade Partners and Origin of Ballast

Disclosure of all ballast water sources for all tanks is a requirement of the ballast water reporting form (Appendix C) and is recorded in the NBWIC. Review and evaluation of this data in conjunction with ballasting data would indicate which ports are most vulnerable. It would seem likely that trade between neighboring ports would pose less of a risk of introduction than ports further away, since neighboring areas may share environments and species. However, this may not always be a valid assumption because sometimes species are very different in neighboring countries, but the environmental conditions may be quite similar; for example, the U.S. Gulf Coast and Mexico (Barrett-O’Leary, 1999). Therefore, it is more important to assess the similarities of the environmental conditions (e.g., geology, climate and water quality characteristics) and indigenous organisms of the trading ports. Species thriving in ports with extremely different water quality and climate characteristics are less likely to survive if transferred, and thus vessels carrying ballast from regions with different water quality characteristics present less risk.

Attention should be directed first to trade vessels with neighboring countries along the Gulf of Mexico and Caribbean with similar environments and significantly different species. Neighboring countries (South and Central America and the Caribbean) represent approximately 40 percent of all entering the Gulf of Mexico vessels (Table 14). Trade with areas of the world like northern Russia or the Scandinavian countries should receive less research attention because the climate is so different that species arriving from those waters are more likely to die than becoming established (Barrett-O’Leary 1999).

Most of the time the U.S. port of call is the port perceived to be at the highest risk of receiving potential invaders. However, the risk for introductions also exists in subsequent U.S. ports. Ships, particularly foreign container or general cargo ships, taking on cargo sequentially from many different Gulf of Mexico ports may be discharging ballast water taken from previous foreign ports of calls, or may be a mixture of domestic and foreign ports. Additionally, in the Gulf of Mexico region, inland trade along the GIWW, as well as coastwise trade between neighboring Gulf ports, provides an opportunity to spread invasive species among ports. Florida, for example, has many aquatic invasive species not found in other Gulf states (Barrett-O’Leary 1999). Data and information on the sources of ballast water being discharged and the trade patterns, both domestic and foreign, are necessary for a full evaluation of the risk of

introductions. Foreign vessels are required to report their last port of call and their next port of call upon entering the U.S. However, no reporting is required in subsequent U.S. ports. As a result, ballasting volumes and operations and ballast water exchange information are accessible through NBWIC only for transit voyages from the foreign origin port to the first U.S. port of call.

6.3 Perspectives from Gulf of Mexico Region Stakeholders

Over the past year three ballast water workshops have been held in the Gulf of Mexico region:

- Invasive Species and Ballast Water Management in the Gulf of Mexico Region, October 1999, New Orleans, Louisiana
- Aquatic Invasive Species and Shipping in the Eastern Gulf of Mexico: A Workshop for the Maritime and Scientific Community, November 1999, Tampa, Florida
- Western Gulf Ballast Water Workshop, April 2000, Houston, Texas

These workshops have either solely focused on the ballast water issue or have addressed it as a major component of invasive species management. During each workshop, national and regional perspectives on ballast water were shared during presentations made by the ports, the shipping industry, environmental managers, and scientists. Workshop participants also shared their opinions on regional management of ballast water and provided suggestions for future actions. The following highlights have been summarized from the workshop proceedings – Grantham and Barrett-O’Leary (1999), Greening and Holland (1999), and Barrett-O’Leary (2000) – and reflect the perspectives and suggestions of the workshop participants.

Ballast Water Management Approaches

The consensus of the participants was that non-regulatory approaches are not likely to be viable. Therefore, regulations are needed to drive ballast water management and treatment strategies. Future regulations should be national (or if possible international) in scope and should establish uniform standards for clean ballast and acceptable levels of risk, but should also allow for regional/local implementation and monitoring. A unified national approach is far superior to establishing varying regulations at local levels. The participants agreed that it is important to support the USCG voluntary approach and SERC efforts to record regional information on ballasting procedures and sources.

By comparison to other areas of the country, the Gulf of Mexico has received little attention for invasive species research. Participants agreed that more regional efforts are needed to raise the visibility of the potential impacts of ballast water introductions within the Gulf of Mexico. To accomplish this goal, the Gulf States need to work together, in the same way that the Great Lakes States do, to influence funding and research.

All workshop participants agreed that a risk assessment approach is necessary to identify and focus efforts on the most probable and damaging species, and the geographic areas within the

Gulf of highest concern. Public health concerns as they relate to ballast water (i.e., imported viruses and bacteria) should be a top priority within the approach. A realistic, scientifically-defensible framework should be developed that accounts for the range and conditions for survival and tolerance levels of potential invaders; the origin of foreign vessels entering Gulf ports; and the environmental conditions of those ports. However, to develop a risk assessment approach, a substantial amount of baseline data needs to be collected to characterize port and ballast water quality and biology.

Ballast Water Treatment Options

There is currently no cost-effective alternative to open-ocean exchange and because of the inherent problems with exchange, viable alternatives are needed. Most workshop participants agreed that shipboard systems that treat ballast water during ballasting operations were the preferred alternative; however, it may be necessary to provide incentives to ship owners for installing these systems. Portside facilities will increase port congestion and ultimately impact port economics. Additionally, construction of portside treatment facilities will require available space and land, both of which are difficult to secure at existing port terminals. The participants agreed that a critical review of all potential treatment options needs to be conducted and that all potential options should be considered, including alternative sources of ballast.

Regional Needs

As a result of discussions during these workshops, the following regional needs were expressed by participants:

- Stronger action needs to be taken regionally to raise political awareness.
- Regional workgroups and forums need to be established to exchange scientific information and to develop management strategies.
- Additional research needs to be conducted to develop methods for preventing invasions.
- Baseline data to support a risk assessment approach is necessary.
- A Gulf-region information clearinghouse needs to be established.
- Educational campaigns targeted at vessel operators need to be initiated locally.
- Public outreach campaigns need to continue.

6.4 The Management Framework for Ballast Water

International Level

Although open ocean exchange of ballast water is currently the best method of controlling nonindigenous species introductions, it is a voluntary practice in most countries. As such, it is impossible to enforce a particular level of exchange. Ballast water management will most effectively be accomplished by international regulations that provide consistent guidelines for all countries.

International Maritime Organization (IMO)

The IMO, a United Nations agency with jurisdiction over maritime affairs, is developing an international framework for ballast water management. In 1997, the members of the IMO adopted the resolution, “Guidelines for the Control and Management of Ships’ Ballast Water to Minimize the Transfer of Harmful Aquatic Organisms and Pathogens.” These are voluntary guidelines that vessel masters and port states can adopt to minimize the risk of spreading nonindigenous species through ballast water. Many countries, including the U.S., have adopted these guidelines and some ships are carrying out open ocean exchanges, as called for in the guidelines. While these voluntary measures are a good first step, the Marine Environmental Protection Committee (MEPC) of the IMO is continuing to develop a binding legal agreement on ballast water management. Current plans are for a final agreement in the 2001-2002 time frame; however, it would still need to be ratified by member nations before it becomes effective, which could take until 2005.

International Convention for the Prevention of Pollution from Ships (MARPOL)

MARPOL is an international treaty that addresses pollution from ships. Shipboard waste from a variety of sources is regulated under six MARPOL annexes, none of which address nonindigenous species in ballast water. The MEPC is promoting a seventh MARPOL annex that covers ballast water management. The IMO’s voluntary guidelines will be used as a basis for developing these mandatory regulations. The new MARPOL annex would include Ballast Water Management Guidelines as well as a Ship’s Ballast Water Management Plan.

International Council for Exploration of the Seas (ICES)

The ICES has convened sessions and symposia focused on reducing the risk of adverse effects from transport and introduction of nonindigenous species. Specifically, the ICES Working Group on Introductions and Transfers of Marine Organisms has included ballast water issues on its agenda since 1988. ICES efforts are focused on the research that is needed to develop control and treatment techniques, understanding the conditions under which ballast water supports a diversity of aquatic organisms, and providing education on managing ballast water.

North American Commission for Environmental Cooperation (CEC)

The CEC’s “Cooperation on the Protection of Marine and Coastal Ecosystems” project has two initiatives, one of which is relevant to nonindigenous species and ballast water. The “Closing the Pathways of Aquatic Invasive Species across North America,” which will develop a coordinated, multinational prevention and control campaign aimed at eliminating pathways for the introduction of invasive species for inland and coastal waters of Canada, Mexico, and the U.S.

National Level

The Nonindigenous Aquatic Nuisance Prevention and Control Act (NANPCA) of 1990 focused on preventing the release of nonindigenous species to the Great Lakes where there has been significant economic and ecological impacts associated with nuisance species introduced through ballast water. The Nonindigenous Invasive Species Act (NISA) of 1996 amended the

1990 Act and pertains to all ships that operate in foreign waters and enter U.S. ports. To comply with ballast water provisions of NISA, the U.S. Coast Guard proposed both regulations and voluntary guidelines in April 1998.

U.S. Coast Guard (USCG) Program

To implement the NISA, the USCG has developed regulations that (1) promote ballast management for operators of all vessels in waters of the U.S., (2) provide voluntary ballast water management guidelines for all vessels entering U.S. waters from outside the EEZ, and (3) require that all vessels entering U.S. waters from outside of the EEZ report ballast water management data. On July 1, 1999, the USCG published an interim rule establishing a program for the voluntary exchange of ballast water from ships prior to entering U.S. ports.

As discussed previously, the USCG, in cooperation with the Smithsonian Environmental Research Center (SERC), has developed a nationwide program to measure ballast water management and delivery patterns for commercial vessels that arrive in U.S. ports from outside the EEZ. This National Ballast Water Survey is designed explicitly to create a national database on ballast water practices. USCG personnel are involved in the collection of data to verify the accuracy of data submitted under the new regulations. In addition, vessel owners and/or operators must submit ballast water management forms to the National Ballast Water Information Center, operated by SERC for the USCG. Results from the ballast water reports may be viewed on the Internet at www.serc.si.edu/invasions/ballast.htm. The USCG plans to implement a mandatory ballast management program if compliance with the voluntary program is determined to be inadequate. In addition to the value that the data from the survey provides to the USCG in evaluating the regulatory approach, the data, as discussed in Section 6.3, will also be invaluable to environmental managers and in assessing the potential risks of introductions to specific ports.

U.S. Environmental Protection Agency (USEPA) Review of Ballast Water Regulation

In response to a petition from a coalition of environmental groups, USEPA indicated that a final decision on whether to revise USEPA's regulations to direct states to regulate ballast water as a point source would not be made until mid-2000. USEPA is currently drafting a white paper that will describe options for regulating the discharge of ballast water, and they plan to work with the USCG to develop possible options. USEPA then expects to coordinate the proposal with its regional offices before releasing it for public review.

American Association of Port Authorities (AAPA)

The AAPA is working with ports and the USCG to identify opportunities for ports to encourage increased compliance among carriers, especially at private bulk-exporting terminals where most ballast water is discharged. The AAPA is working with government, industry, and private maritime stakeholders to address the problem of terrestrial pests as well as the emerging problem of nonindigenous aquatic organisms. The AAPA is currently working with the U.S. government and other maritime stakeholders to promote a binding international agreement that eliminates the spread of nonindigenous aquatic species with the least disruption to existing commercial shipping practices.

Northeast-Midwest Institute (NMI)

The NMI is a private, non-profit, and non-partisan research organization dedicated to economic vitality, environmental quality, and regional equity for Northeast and Midwest states. Aquatic invasive species is one of NMI's priority issues and has been active in four main arenas: congressional authorizing and appropriating legislation to prevent and control the spread of aquatic nuisance species; oversight of program implementation; ship-board ballast treatment technology development; and development of an international convention on ballast water management as part of the IMO. On December 2-3, 1999, NMI held a discussion forum, "The NISA Ballast Management Program: Opportunities to Add Value through Partnerships," to attempted to outline opportunities for interested entities to cooperatively enhance the NISA Ballast Management Program.

Gulf Coast Regional Maritime Technology Center

The Gulf Coast Regional Maritime Technology Center, headquartered at the University of New Orleans, is an organization established in late 1994 through a cooperative agreement with the Office of Naval Research. The main purpose of the Center is to enhance the competitiveness of the U.S. maritime industry in the international market by promoting and supporting the application of basic research processes in maritime technology development.

State Level

A number of states are focusing attention on the issue of nonindigenous species and ballast water. For example:

- The California legislature passed a bill last year establishing a ballast water management program. Vessels entering a California port from outside the U.S. EEZ must pay a fee of \$400 and submit the USCG's ballast water management form to the State Lands Commission.
- The Maryland legislature considered a bill that would essentially adopt the USCG program.
- A bill similar to the USCG program was developed in the State of Washington, but this bill would make ballast exchange mandatory (except when safety is at risk) on all voyages including coastwide trades. Additionally, as an incentive to develop ballast water treatment technologies, all ballast water discharged into state waters after July 2000 would have to be treated.
- A bill introduced to the Michigan legislature required that ballast water be "sterilized" before discharge into state water.
- Ballast water legislation has been introduced to the Ohio legislature.

To date, no ballast water management bills have been introduced in the legislatures of the five Gulf States.

Individual Port Initiatives

Several ports have implemented individual ballast water research, reporting, and management programs. For example, the Port of Oakland (California) recently proposed to require ships using its facilities to discharge ballast water at sea. The Port modeled their requirements after those being used in Vancouver (Canada). The Port is on record as favoring uniform national regulations for ballast water in order to provide a level playing field for all U.S. ports. In addition, the California Association of Port Authorities is sponsoring a study of ballast water management technologies.

In the Gulf region, the port authorities in Corpus Christi and Houston have made public statements at regional ballast water workshops about implementing some ballast water management plan, if warranted after their own internal research (Barrett-O'Leary, pers. comm.). Regional National Estuary Programs have also identified introductions of invasive species as a priority issue. The Coastal Bend Bays National Estuary Program (CCBNEP) included ballast water management planning as one of its Comprehensive Conservation and Management Plan Actions. Under this action the CCBNEP plans to educate vessel owners and operators on the impacts of ballast operations and identify the vessels entering the port of Corpus Christi that pose the highest risk through the evaluation of trade partners, ballasting operations and compliance with the voluntary guidelines.

7.0 The Management Framework for Addressing Invasive Species Issues in the Gulf of Mexico Region

"In a global economy, we must fight a global war against invasive pests and diseases."

U.S. Department of Agriculture Secretary Dan Glickman, March 17, 2000

Section 7.0 describes the roles of government and private entities that contribute to the collective management of invasive species issues in the Gulf of Mexico region. Organizations discussed are not limited to those addressing only *aquatic* invasive species. While a thorough inventory of organizations is discussed in this section, it is by no means comprehensive. In fact, the Invasive Species Council report, *National Management Plan: Meeting the Invasive Species Challenge* (the final version – dated January 18, 2001 – is available at www.invasivespecies.gov), contains an extremely detailed description of the federal and international management framework for invasive species, and augments and updates related information in this section.

7.1 General Overview of the Available Management Framework

Invasive species problems arise in seemingly disconnected crises and species, and there is general consensus that both federal and state legislation have been developed in a reactionary fashion, as each crisis was addressed (ISC 2000). At the federal level, the current management framework has its foundation in over 28 pieces of legislation and is dependent on activities of more than two dozen different federal agencies. Some of these laws and activities only peripherally address invasive species; others cover related issues in a manner unintended in the original legislation. The laws addressing threats to agriculture – for centuries a well-developed U.S. industry whose risks from invasions were relatively clear – tend to be more developed than laws protecting ecosystems or other industries (Corn *et al.* 1999). For example, laws protecting industries such as tourism and electric power and water supplies are far less developed and, in some cases, do not exist.

With no single law, or coordinated group of laws, providing coordination among federal agencies in addressing invasive species concerns, the Office of Technology Assessment (OTA) (1993) determined that “the current federal framework is a largely uncoordinated patchwork of laws, regulations, policies, and programs.” In general, there are substantial gaps in federal laws

and programs to prevent the introduction of nonindigenous species, and it is clear that significant risks remain unaddressed (ISC 2000).

Existing legislation is targeted toward both controlling particular species and regulating specific vectors. Species-oriented legislation prohibits or regulates introduction of species that have caused problems, or have the potential to cause problems. Much of the current federal and state legislation contains lists of prohibited and restricted species. For prohibited lists, it is usually illegal to import, sell, possess, or transport those species; restricted species can usually be imported, cultured, sold, and/or transported with one or more permits from appropriate natural resource agencies. Agency rules, and associated permits, for restricted species often differentiate between releases to human control and confinement (e.g., aquaculture, ornamental fish farms, research facilities, public aquaria) and releases to open ecosystems.

Hawaii is unique among the U.S. state for using a “clean list” approach, which prohibits all nonindigenous species introductions except those that are evaluated and determined not to be injurious (Fletcher 2000). However, the clean list approach can be overly restrictive to reasonable economic activity and would be difficult to implement in a state like Florida with its long-established ornamental fish industry (Hill 2001).

It has been suggested that many currently implemented vector-based controls are compromised by understaffing and time pressure (Ruesink et al. 1995). For example, for foreign imports, the volume of trade creates a tremendous burden on an understaffed federal inspection system and forces a strong reliance on self-reporting by the shipping industry (OTA 1993). Equally problematic, there has been little support for regulations addressing unintentional “by-product” introductions (Corn et al. 1999). However, recent efforts to manage ballast water discharges represent a serious legislative attempt to control a high-risk introduction vector.

Some researchers contend that a consensus is developing that the invasive species problem has reached proportions demanding a coherent national policy to guide future actions (Williams and Meffe 1999). In 1997, more than 500 scientists and natural resource managers wrote the Clinton Administration to express their deep concern about the damage done by invasive species every year (ISC 2000). This action resulted in the establishment of a national Invasive Species Council (ISC), through Presidential Executive Order, which issued a national invasive species management plan in January 2001. At the same time, the recognition of federal framework limitations has initiated state and regional management and planning (Fletcher 2000).

Universally it is recognized the prevention of new introductions of invasive species, and the immediate eradication of new colonies of invasive species, is the most effective, and cost effective, method to control invasive species (Mack et al. 2000). Risk-based decision-making approaches, based on available information, can help managers to quantitatively evaluate the likelihood of an undesired event and the likelihood of harm or damage being caused (Hayes 1998). At this time though risk-based decision criteria are currently absent from most U.S. policy for intentional introductions. However, the ANSTF recently presented a generic nonindigenous aquatic organisms risk analysis review process (ANSTF 1996), and Hayes (1998) has recently presented a suggested approach for an ecological risk assessment for ballast water introductions. Some researchers and managers advocate the implementation of zero-risk policies

at national and international levels (Mack et al. 2000), assumably for species introductions to open ecosystems versus imports to human control and confinement (e.g., aquaculture).

Given the magnitude of active introduction pathways and the diversity of nonindigenous species and receiving ecosystems, an adaptive management approach will have to be adopted. This way the relative ecological, economic, and human health threats posed by invasive nonindigenous species will periodically re-prioritize prevention, management, control, and public education efforts to yield the most benefit for the environment, economic vitality, and human health. In addition, management of invasive species ultimately must be a global endeavor. Efforts to restrict invasive species introductions to the U.S. will be aided through coordination with the countries-of-origin for these species (ISC 2000).

General Analysis of Gulf State Management Provisions

All five Gulf States have statutory provisions applicable to nonindigenous species introductions, and specific provisions applicable to at least selected aquatic species (specific Gulf State statutes and regulations are described in Sections 7.5 through 7.9). Each Gulf State maintains prohibited and/or restricted species lists, and conducts permit programs to regulate the import, possession, sale, and transport of selected species.

To date, none of the five Gulf States has established a comprehensive invasive species management plan, although plans for a few plant species have been developed in Florida (FEPPC 1997, FEPPC 1999). However, planning efforts are beginning at both the state and regional levels (Texas Sea Grant Program 1998). In the summer of 2000, the Louisiana Sea Grant Program sponsored the state's first meeting to discuss development of an invasive species management plan (Barrett O'Leary, pers. comm.). Likewise, Florida Governor Jeb Bush recently requested that the Florida Department of Environmental Protection (FDEP) facilitate a meeting of Florida's state agencies to determine the most effective way to develop a comprehensive invasive species management plan (Bush 2000).

Two primary statutes and a noxious weed program in Florida, Texas's Statewide Vegetation Management Plan, and Alabama's Nonindigenous Aquatic Plant Control Act, appear to adequately address invasive plants in those states. In fact, the Florida and Texas statutes and programs could serve as good models for state invasive species management plans, as they provide a lead executing agency, scientific research directives, prohibitions on introductions, and grant programs for local agencies (Fletcher 2000). However, in both of these cases, the states do not have provisions applicable to freshwater and saltwater animals: statutory authorities would have to be expanded for truly comprehensive planning. In Texas and Louisiana nonindigenous animal restrictions are basically a patchwork of aquaculture and wildlife provisions (Fletcher 2000).

With respect to regional planning, Fletcher (2000) indicates that no Gulf State statutes provide (1) provisions to offer notice of identifications, introductions, or infestations to neighboring states or (2) any provisions for mitigation. Without such provisions, significant conflict can occur among states when a nonindigenous species introduction is intentional and controversial (Fletcher 2000).

7.2 Federal Level

Federal Laws

The array of federal laws that affect invasive species management, prevention, and control generally fall into three categories: (1) statutes and treaties that restrict importation through trade regulation (and sometimes interstate movement) of intentional introductions or organisms brought into the U.S. for specific purposes; (2) statutes that address unintentional introductions of organisms as an adjunct to other commercial activity; and (3) environmental legislation for land management (organic acts) and other conservation and natural resources laws that require consideration of risks and cumulative impacts to natural resources and systems, including species at risk of extinction (ISC 2000). Table 15 provides summary descriptions of the applicable federal laws and Appendix D provides a more detailed description of most of these laws.

Table 15. Federal Laws Regulating Introduction and Movement of Nonindigenous Species

Federal Law	Summary Description
Lacey Act (1900)	Strengthens and supports state wildlife conservation laws and promotes agricultural and horticultural interests by prohibiting importation of injurious wildlife.
Plant Quarantine Act (1912)	Regulates imports or interstate shipments of plants or their parts and propagates to prevent introduction of plant diseases and insect pests.
National Park Service Organic Act (1916)	Promotes the eradication and control of nonindigenous species and prohibits most introductions in national parks.
Animal Damage Control Act (1931)	Provides the Animal and Plant Health Inspection Service with the authority to control wildlife damage (including nonindigenous species) on federal, state, and private land.
Federal Seed Act (1939)	Authorizes U.S. Department of Agriculture to set standards for seed purity and to reduce the interstate movement and importation of nonindigenous plants.
Public Health Services Act (1944)	Regulates entry of living organisms that may carry or cause human diseases.
Organic Act (1944)	Forms the basis of the Animal and Plant Health Inspection Service's domestic detection, eradication, control, and prevention efforts with regard to plant pests.
Federal Insecticide, Fungicide, and Rodenticide Act (1947)	Controls movement of nonindigenous microbes into and through the U.S.
Importation of Certain Mollusks (1951)	Provides for the inspection and treatment of goods entering the U.S. from areas infested with any terrestrial or freshwater mollusks to control entry of such organisms.
Department of Agriculture Organic Act (1956)	Animal and Plant Health Inspection Service is authorized to conduct an eradication program in countries adjacent to or near the U.S.
Federal Plant Pest Act (1957)	Restricts agricultural pests (pathogens, noxious weeds, animal, and plant pests) from importation and interstate movements.
National Environmental Policy Act (1970)	Requires federal government agencies to consider the environmental effects of their actions through the preparation of environmental impact statements—possible applications to nonindigenous species.
Marine Protection, Reserves, and Sanctuaries Act (1972)	Releases of ballast water might be permitted or otherwise controlled under ocean dumping provisions.
Endangered Species Act (1973)	Protections for rare species may provide vehicle for regulation of nonindigenous species.

Federal Law	Summary Description
Federal Noxious Weed Act (1974)	Provides program support to control undesirable plants on federal lands.
Executive Order 11987 Exotic Organisms (1977)	Restricts the introduction of exotic species into natural ecosystems under federal agency authority.
Cooperative Forestry Assistance Act (1978)	Detects, identifies, surveys, and controls forest pests.
Act to Prevent Pollution from Ships (1980)	The Act, as amended by the Marine Plastic Pollution Research and Control Act of 1987, requires ships in U.S. waters to comply with the International Convention for the Prevention of Pollution from Ships.
Clean Water Act (as amended in 1987)	Releases of ballast water might be permitted or otherwise controlled under sections 402 National Pollutant Discharge Elimination System and 303(d) Total Maximum Daily Load program.
Agricultural Quarantine Enforcement Act (1989)	Prohibits shipping of plants, fruits, and vegetables via first-class mail.
Food, Agriculture, Conservation, and Trade Act (1990)	Establishes Genetic Resources Program to collect, classify, preserve, and disseminate genetic material important to agriculture.
Great Lakes Fish and Wildlife Restoration Act (1990)	Controls the sea lamprey.
Toxic Substances Control Act (1990)	Enables USEPA to regulate nonindigenous microbes.
Nonindigenous Aquatic Nuisance Prevention and Control Act (1990)	Controls and reduces the spread of aquatic pest species.
Alien Species Prevention and Enforcement Act (1992)	Prohibits the shipping of certain categories of plants and animals through the mail.
Wild Bird Conservation Act (1992)	Regulates the importation of certain wild birds, which may reduce the associated importation of nonindigenous parasites and diseases.
Hawaii Tropical Forest Recovery Act (1992)	Addresses the problems of the native forests of Hawaii, including the introduction of nonindigenous species.
National Invasive Species Act (1996)	Amended the NANPCA of 1990. Prevents the introduction and spread of aquatic nuisance species into the Great Lakes through ballast water and other vessel operations. Encourages international program to prevent the introduction and spread of invasive species in ballast water.
Executive Order 13112 Invasive Species (1999)	Prevents the introduction of invasive species, provides for their control, and then reduces impacts through improved coordinated federal agency efforts under a National Invasive Species Management Plan.

Sources: Corn et al. (1999) and Williams and Meffe (1999).

Federal Agency Responsibilities

The OTA (1993) reports that federal activities occur in several areas:

- *Movement of species into the U.S.* Restricting entry of harmful nonindigenous species by regulation, inspection, and quarantine, or enhancing entry by intentional importation of desirable species, or by importation of materials that unintentionally harbor harmful nonindigenous species.
- *Movement of species within the U.S. across state lines.* Restricting movement of harmful nonindigenous species by regulation, inspection, and quarantine, or enhancing movement of desirable nonindigenous species by intentional transfers, or by transporting materials that unintentionally harbor nonindigenous species.

- *Regulating product content or labeling.* Restricting entry or interstate movement of harmful nonindigenous species by regulating contamination or mislabeling of nonindigenous species in commerce.
- *Controlling or eradicating harmful nonindigenous species.*
- *Introducing desirable nonindigenous species.*
- *Federal land management.* Preventing, eradicating, or controlling harmful nonindigenous species on federal lands and introducing or maintaining desirable nonindigenous species on federal lands.
- *Nonindigenous and invasive species research.* Addressing prevention, control, and eradication of harmful nonindigenous species and beneficial uses of nonindigenous species.
- *Aquaculture development.*
- *Biocontrol development.*

Appendix E is a matrix presenting the areas in which each federal agency is involved. Appendix F is a matrix that presents federal agency coverage as it relates to major species groups. Appendix G provides detailed descriptions of the roles and responsibilities of the following federal agencies:

U.S. Department of Agriculture (USDA)	<ul style="list-style-type: none"> • Agricultural Research Service (ARS) • Animal and Plant Health inspection Service (APHIS) • Cooperative State Research, Education, and Extension Service (CSREES) • Economic Research Service (ERS) • Farm Service Agency (FSA) • U.S. Forest Service (USFS)
U.S. Department of Commerce	<ul style="list-style-type: none"> • National Oceanic and Atmospheric Administration (NOAA) • National Sea Grant College Program
U.S. Department of Defense	<ul style="list-style-type: none"> • U.S. Army Corps of Engineers (USACE)
U.S. Department of the Interior	<ul style="list-style-type: none"> • Bureau of Land Management (BLM) • U.S. Fish and Wildlife Service (USFWS) • U.S. Geological Survey (USGS) • National Park Service (NPS) • Office of Surface Mining Reclamation and Enforcement (OSM)
U.S. Department of State	<ul style="list-style-type: none"> • Department of State
U.S. Department of Transportation	<ul style="list-style-type: none"> • U.S. Coast Guard (USCG) • Federal Highway Administration (FHA)
Independent Agencies	<ul style="list-style-type: none"> • Council on Environmental Quality (CEQ) • U.S. Environmental Protection Agency (USEPA) • National Science Foundation (NSF) • Smithsonian Institution
Interagency Efforts	<ul style="list-style-type: none"> • Federal Interagency Committee for Management of Noxious and Exotic Weeds (FICMNEW)

Aquatic Nuisance Species Task Force (ANSTF)

The NANPCA of 1990 created the ANSTF to provide, in an advisory capacity, an intergovernmental organization for the development of a coordinated federal program to control

aquatic nuisance species. The ANSTF consists of seven federal agency representatives and ten ex-officio members. It is co-chaired by the USFWS and NOAA; other participating federal agencies are USEPA, USCG, USACE, USDA, and the U.S. Department of State. The ANSTF is responsible for all aspects of the Act other than those associated with Great Lakes ballast water and national shipping programs. Specific responsibilities are to:

- Develop a program for U.S. waters to prevent the introduction and dispersal of aquatic nuisance species and the brown tree snake, to monitor, control and study such species, and to disseminate information.
- Establish and follow a protocol to ensure that research carried out under the Act does not result in the introduction of aquatic nuisance species to U.S. waters.
- Conduct a biological study and ballast exchange study and ecological surveys.
- Recommend allocation of funds authorized under the Act for competitive research grants to study all aspects of aquatic nuisance species.
- Develop voluntary guidelines to control the spread of zebra mussels and other aquatic nuisance species through recreational activities, including boating and fishing.
- Request the Great Lakes Commission to convene a panel of Great Lakes representatives to provide advice about and coordinate efforts devoted to aquatic nuisance species in the Great Lakes.
- Establish and use the Western Regional Panel and encourage the development and use of other regional panels.
- Provide technical assistance in the development and implementation of state and interstate aquatic nuisance species management plans, review and approve such plans, and make recommendations for grants to implement approved plans.
- Advise the Secretary of State regarding aquatic nuisance species infesting waters shared by the U.S. and other nations, as well as, planning and implementation programs to prevent, monitor, study, provide education about, and control those infestations.

The partnership that is the ANSTF has initiatives and activities underway in the following action categories: (1) biological case studies and ecological surveys; (2) control programs; (3) prevention initiatives; (4) risk assessments and reviews; (5) policies; and (6) protocols and guidance. Most of these activities are coordinated by the ANSTF through standing or ad-hoc committees and subcommittees. The following subsection highlights one of such activity.

National Voluntary Aquatic Nuisance Species Guidelines for Recreational Activities

The ANSTF established a Recreational Activities Committee to draft voluntary guidelines to prevent the spread of zebra mussels and other aquatic nuisance species through boating, fishing, and other recreational activities. The USCG must issue these voluntary guidelines, based on the recommendations prepared by the ANSTF, to comply with the NISA of 1996.

The purpose of the voluntary guidelines is to provide clear, concise information for dissemination to the public, identifying specific practices that can be undertaken to minimize or avoid transport of aquatic nuisance species. The Committee, chaired by the USFWS, is comprised of representatives from numerous other organizations and agencies. The Committee adopted the following strategy: (1) develop generic guidelines; (2) identify the potential

recreational pathways of spread; (3) develop specific guidelines for the various recreational pathways; and (4) identify potential partners to participate in disseminating and implementing the guidelines.

The USCG is currently seeking comments on *Voluntary Guidelines on Recreational Activities To Control the Spread of Zebra Mussels and Other Aquatic Nuisance Species*. These voluntary guidelines are for persons engaged in water-related recreational activities (e.g., boating and fishing) to help control the spread of the zebra mussel and other aquatic nuisance species.

Invasive Species Council (ISC)

The ISC was established by Executive Order 13112. It is co-chaired by the Secretaries of the Departments of Interior, Agriculture, and Commerce; other members of the Council include the Secretaries of Departments of State, Treasury, Defense, and Transportation, and the Administrator of USEPA. Other agencies and subcabinet offices may be added as necessary. The ISC is managed by an Executive Director and staff supplied by the U.S. Department of Interior. The ISC established an advisory committee under the Federal Advisory Committee Act to provide information and advice in achieving the goals and objectives of the Executive Order.

The ISC provides national leadership regarding invasive species by:

- Overseeing implementation of the order in conjunction with the agencies and existing organizations such as the ANSTF, FICMNEW, and the Committee on Environment and Natural Resources;
- Encouraging planning and action at local, tribal, State, regional, and ecosystem-based levels in cooperation with stakeholders and existing organizations;
- Developing recommendations for international cooperation;
- Coordinating with the Council on Environmental Quality;
- Developing guidance to federal agencies pursuant to the National Environmental Policy Act for inclusion of invasive species in Environmental Impact Assessments;
- Facilitating development of a coordinated federal agency network to document, evaluate, and monitor impacts from nonindigenous species;
- Establishing a coordinated information-sharing system that collects information on nonindigenous species including distribution and abundance of nonindigenous species; life histories; invasive characteristics; economic, environmental and human health impacts; management techniques; and laws and programs for management, research and public education;
- Preparing and issuing a National Invasive Species Management Plan.

The ISC issued the first draft of *United States Invasive Species Draft Management Plan: Preparing for the Future* on July 10, 2000. The draft Management Plan is divided into four sections. The first section briefly describes problems associated with invasive species and future trends that will impact the introduction of invasive species. The second section describes the federal response to date to the challenges presented by invasive species, providing a brief summary of authorities and management approaches and a discussion of gaps in those authorities

and approaches. The Action Plan presents a vision and guiding principles and a series of recommendations for federal agencies that focus on the next few years, as well as measures that can be achieved over the longer term. This third section includes strategies to reduce the risk of invasive species introductions and identifies research priorities. The Council Progress and Action section, the fourth section, describes the work of the Council to date and actions that the ISC will take over the next few years prior to revision of the management plan. It also provides accountability measures that hold the ISC responsible for seeing that the plan is carried out.

The ISC will update the Management Plan biennially and will concurrently evaluate and report on success in achieving the goals and objectives described in the Management Plan. The Plan will identify the personnel, other resources, and additional levels of coordination needed to reduce the threat of nonindigenous species.

U.S. Coral Reef Task Force

The U.S. Coral Reef Task Force has developed the National Action Plan to Conserve Coral Reefs (issued in March of 2000), which identifies invasive alien species as one of the specific and widely accepted threats to coral reefs requiring immediate action. The Plan calls for specific actions to address nonindigenous species threats to coral reefs utilizing existing authorities among various federal and state agencies.

7.3 Regional Level

The OTA (1993) determined that conflicts, particularly regarding nonindigenous aquatic species releases, arise among states because of their differing ecological, economic, and policy contexts. States lack the power to stop the importation and release of a potentially invasive nonindigenous species in a neighboring state. Since few federal laws compel states to cooperate with each other, and states have differing priorities, conflicts can and do occur. Sometimes no mechanism exists for resolving conflicts between states short of a federal lawsuit.

Regional approaches provide opportunities for states to resolve their differences and influence the actions of neighboring states. Such approaches have been used most frequently for evaluating aquatic releases, and several regional entities exist with a specific role to coordinate introduction policies across a particular region. For example, the Gulf States Marine Fisheries Commission provides the venue for state officials to agree on guidelines for releases, inspections, and permits. Expanding the use of regional approaches for other types of releases appears promising, but is limited by their voluntary nature. The regional organizations that exist, however, provide important forums for proactively addressing potential differences.

Gulf of Mexico Regional Panel

Over the last decade, substantial progress has been made in documenting and responding to nonindigenous species and their associated impacts. The NANPCA of 1990 established the first institutional framework for national policy and programmatic response to the issue. The role of regional, multi-jurisdictional organizations has been growing significantly with the recognition

that prevention and control efforts are more effective when administered on a hydrologic (i.e. ecosystem) basis, as opposed to a geopolitical basis. A regional, multi-jurisdictional approach to the aquatic nuisance species issue was further emphasized with the passage of the NISA of 1996 which fosters and encourages the development of regional panels by the ANSTF to advance prevention and control efforts. These panels serve in a voluntary capacity to provide the ANSTF with (1) regional input on emerging invasive species issues, (2) coordination of regional programs involved in controlling invasive species, and (3) development of recommendations on policy and/or program actions that are recommended to be undertaken at the national level by the organizations represented by the ANSTF.

In 1998, the ANSTF invited the GMP to serve as the Gulf of Mexico Regional Panel. The structure of the GMP's Management Committee is ideally suited, by virtue of its broad organizational management representation, to serve as the Gulf Regional Panel. The Invasive Species Focus Team provides the technical expertise in identifying, evaluating, and preparing characterizations of and recommendations on invasive species issues and initiatives in the Gulf of Mexico region.

The Management Committee's responsibilities as Gulf of Mexico Regional Panel include the following:

- Identify Gulf regional priorities for responding to aquatic nuisance species;
- Make recommendations to the ANSTF regarding education, monitoring, and prevention of aquatic nuisance species in the Gulf region;
- Coordinate other Gulf aquatic nuisance species program activities not pursuant to the Act;
- Develop an emergency response strategy for federal, state, and local entities for the purpose of eliminating new invasions of aquatic nuisance species in the Gulf;
- Provide advice to public and private individuals and entities across the Gulf region concerning methods of preventing and controlling aquatic nuisance species infestations; and
- Submit an annual report to the ANSTF describing the Gulf region's invasive species management activities.

The first official meeting of the Gulf of Mexico Regional Panel was held in October 1999 in Galveston, Texas. The Gulf Regional Panel is identifying regional priorities, developing a workplan, and developing an emergency response strategy for federal, state and local entities. In addition, the panel is developing comprehensive outreach and education strategies.

100th Meridian Initiative

The USFWS initiated the 100th Meridian Initiative as a means of preventing the spread of zebra mussels west of the 100th meridian. Initial surveys of boats being transported through Texas indicate that boats may not be a significant vector for transport of zebra mussels across this meridian (McKinney 2000). The USFWS will probably reevaluate boat survey strategies over the next year and focus on other pathways for transport of zebra mussels west of the 100th meridian.

Gulf States Marine Fisheries Commission (GSMFC)

The GSMFC is an organization of the five Gulf States. This compact, authorized under Public Law 81-66, was signed by representatives of the Governors of the five Gulf States on July 16, 1949, at Mobile, Alabama. It has as its principal objective the conservation, development, and full utilization of the fishery resources of the Gulf of Mexico, to provide food, employment, income, and recreation to the people of these United States.

During a recent GSMFC meeting, there was a discussion about the need for state plans for the prevention and control of nonindigenous aquatic species. Subtitle C, Section 1204(a) of the NANPCA of 1990 calls for the development of state plans to assist states and the federal government in establishing programs. As a result of those discussions, the GSMFC formally recommended that the Governors of the five Gulf States proceed rapidly to develop state plans (GSMFC 1999, Fletcher 2000). Through a variety of venues, including the GMP, the GSMFC Sport Fish Restoration Administrative Program will be engaged in planning activities to move this effort forward.

Lower Mississippi River Council

On March 20 to 23, 2000 the first joint meeting of the Upper Mississippi River Conservation Committee (UMRCC) and the Lower Mississippi River Conservation Committee (LMRCC) was held in Cape Girardeau, Missouri. Resource professionals from the entire length of the Mississippi River met to discuss river resource issues. One of the most critical issues addressed was that of nonindigenous species. One of the primary reasons for the continuing influx of nonindigenous species to North America is a lack of federal legislation regulating intentional and accidental importation of these organisms. Both the LMRCC and UMRCC strongly advocate the need for federal action, in cooperation with the states and private industry, to alleviate this problem. Federal action is also needed to require that any imported species be proven innocuous before it is allowed to enter the country.

South Florida Ecosystem Restoration Task Force (SFER Task Force)

In 1993 a federal Ecosystem Restoration Task Force was established by interagency agreement to develop “consistent policies, strategies, plans, and priorities for addressing the environmental concerns of the South Florida ecosystem.” The Task Force was later formalized and expanded to include tribal, state, and local governments by the 1996 Water Resources Development Act (WRDA). The purpose of the expanded SFER Task Force is to develop and implement a comprehensive plan for restoring, preserving, and protecting the South Florida ecosystem. In this capacity it serves as an information clearinghouse (for example, the Internet-based South Florida Restoration Science Forum) and a coordinating entity that guides the restoration effort and ensures fiscal accountability. Invasive species is one of the SFER Task Force’s priority issues.

The 1996 WRDA specified that the SFER Task Force establish a Florida-based working group, which includes representatives of the agencies and entities represented on the SFER Task Force as well as other governmental entities, for the purpose of formulating, recommending,

coordinating, and implementing the policies, strategies, plans, programs, projects, activities, and priorities of the Task Force.

7.4 Federal-State Relationships

Section 7.4 was excerpted from OTA (1993).

Few generalizations can be made regarding federal-state relationships concerning nonindigenous species. The authority of the federal and state governments varies not only with the type of organism regulated, but also depending on the particular federal and state laws and agencies involved. Mainly, however, states control the entry of nonindigenous species across state borders and release of nonindigenous species within the state. Often these are pests, of either foreign or U.S. origin, that are already established elsewhere in the country. For fish and wildlife, states retain almost unlimited power, notwithstanding the Federal Lacey Act, to make decisions about which species are imported and/or released. Federal incursions on this traditional state control over fish and wildlife have been limited and controversial. In contrast, several major federal laws – such as the Federal Plant Pest Act and the Federal Noxious Weed Act – set national policy for weeds and other plant pests.

Where federal programs miss significant problems, states, in effect, determine the success of nationwide efforts to manage harmful nonindigenous species. There are important limits to the states' capacities, however. The U.S. Constitution vests the power to regulate international and interstate commerce in Congress. Therefore, states cannot unnecessarily restrict such commerce. As a result of the Commerce Clause, states lack the power to stop the importation and release of a potentially invasive nonindigenous species in a neighboring state.

None of the Gulf States has sufficient geographical barriers against the interstate spread of nonindigenous species, and only Texas land bordering Mexico has border inspection stations to interdict pests in transit. Without these kinds of barriers, a state cannot do much to slow the influx of state-prohibited plants or seeds that were acquired legally in another state or country. Nor can a state effectively stop mail-order sales of plants or seeds it prohibits, as policing the mails is a federal function. In addition, states cannot legislate in direct conflict with federal law. Nor can they directly regulate activities on federal lands, absent a cooperative agreement. Occasionally, federal laws explicitly preempt state involvement.

Federal Preemption of State Law

The finding of the OTA is that federal preemption of state law varies among categories of nonindigenous species; it is more common in agricultural laws than in those related to fish and wildlife – traditionally an area of state prerogatives. Cooperative programs are a more feasible way for the federal government to influence state actions.

A key issue in the relationship between federal and state authorities is whether an applicable federal law preempts state laws, keeping states from legislating in the area. This occurs when the federal law explicitly or implicitly provides for preemption, or regulates an area so comprehensively as to leave no practical state role. The Lacey Act required that a list of

“injurious” species or groups be created and it preempts states from allowing foreign importation of the 23 “injurious” taxonomic categories of fish, wildlife, and fish pathogens on that list. The Lacey Act does not, however, forbid more restrictive state laws.

Similarly, no state may permit foreign importation of a weed species prohibited and listed under the federal Noxious Weed Act, although it does not otherwise preempt state weed laws. The federal Plant Quarantine Act also allows states to be more restrictive under certain circumstances, but it imposes a strong federal presence. For example, the federal government can quarantine an entire state under the Act. The federal Plant Pest Act similarly provides strong emergency authority to override state laws.

The federal power to preempt does not mean that the federal approach is always the best. Some state laws regulate more comprehensively than parallel federal laws and their implementation is more effective. Such states are, in effect, laboratories where different approaches are tested; their successes can spawn federal imitation. Nevertheless, when states adopt widely varying laws, the regulated industries may support federally imposed uniformity to facilitate commerce.

Using federal preemptive powers to implement a national approach is fraught with political difficulties – especially for fish and wildlife – and usually engenders resistance from the states. Thus, the trend is toward programs administered cooperatively by state and federal officials. In these the federal government provides incentives to pull, and sanctions to push, the states toward certain general goals or national minimum standards. Several points made in a 1987 USFWS discussion paper on aquatic introductions appear applicable to nonindigenous species introductions in general:

“Introduced aquatic organism issues are inherently interjurisdictional and, thus, clearly national, indeed international in scope. Despite this federal interest, however, emergence of a fully effective program for avoiding undesirable introductions of aquatic organisms requires that involvement by the federal government not preempt state authority. Rather, the federal government should function as a catalyst/facilitator establishing incentives for action by the states and the other co-managers of the Nation’s fishery resources. However, it will also be imperative to ensure universal applicability of any action. Although it must be exercised as a last resort, a credible threat of federal sanctions against non-complying jurisdictions is essential to ensure uniform and, therefore, fair application of any corrective strategy.”

Congress has previously recognized circumstances that justify overriding state management of nonindigenous species when it conflicted with federal goals. Under this reasoning, other states could be compelled to manage nonindigenous species to prevent conflicts with threatened or endangered species. Thus, there could be instances of federal preemption even in the traditionally state-dominated area of fish and wildlife management.

Federal-State Cooperation

Cooperative programs serve several key functions in federal and state efforts. Many provide a means for developing consistent strategies in areas of common concern. Federal and state

agricultural officials, for example, collaborate in the regulation of nonindigenous species importation, interstate commerce, and control.

Certain programs aim for consistent goals in the management and control of harmful nonindigenous species across a geographic region; it does little good for an invasive species to be controlled in one area but not in adjacent areas from which it can re-invade. The 1990 amendment to the Noxious Weed Act acknowledged this by requiring federal land managers to control state-prohibited weeds. Several other cooperative programs for nonindigenous weeds are voluntary, for example, Florida's Exotic Pest Plant Council, which enhances cooperation among control efforts primarily for non-agricultural weeds.

Some programs allow targeting of federal funds or technical assistance to the states for actions serving both national and state needs. The USACE oversees a program for the control of aquatic weeds in which state or local governments can partially recover costs for weed control in navigable waterways. The USFWS provides information and expertise on diseases affecting aquaculture, an area where no comprehensive federal program currently exists.

In some areas, the federal government assists or provides funds to address state needs. Sometimes these programs rely on federal powers. Also, federal inspectors at ports of entry in a particular state may help interdict species prohibited by that State, even if they are not federally listed. Federal assistance for local problems makes sense if, over the long run, they may become national ones (e.g., a rapidly spreading nonindigenous species) or if local problems are so common they become a national concern. The NANPCA of 1990 provides for state submission of comprehensive invasive species management plans. States with approved plans may receive federal matching grants for implementation.

7.5 State Level: Alabama

The Nonindigenous Aquatic Plant Control Act is Alabama's primary nonindigenous species statute (Alabama Code §9-20-1 - 7 (1975 & Supp. 1999)). Section 9-20-1 states that "any person who introduces, places, or causes to be introduced or placed, any nonindigenous aquatic plant into any public waters of the state shall be in violation of this chapter." Authority is given to Alabama Department of Conservation and Natural Resources (ADCNR) to carry out the act's provisions and establish standards for its enforcement. Table 16 lists aquatic plant species prohibited under the act's authority.

Section 9-2-13 gives the Commissioner of ADCNR the authority to "prohibit by duly promulgated regulation, the importation of any bird, animal, reptile, amphibian, or fish when the importation of such animal, bird, reptile, amphibian, or fish would not be in the best interest of the state." The ADCNR Division of Wildlife and Freshwater Fisheries has in place regulations prohibiting the placement or introduction of several fishes and one aquatic mammal that are nonindigenous to the state. However, in most instances, these regulations serve to control the spread of these species, not prevent their original introduction (Minton 2000). These regulations state that "no person, firm or corporation, or association shall possess, sell, offer for sale, import,

bring or cause to be imported into the State of Alabama” certain species: Table 17 lists the fishes and mammal prohibited under these regulations.

Table 16. Prohibited Plant Species in Alabama

Scientific Name	Common Name
<i>Aloe sp.</i>	Water-aloe
<i>Alternanthera philoxeroides</i>	Alligatorweed
<i>Egeria densa</i>	Brazilian elodea
<i>Eichhornia azurea</i>	Rooted waterhyacinth
<i>Eichhornia crassipes</i>	Floating waterhyacinth
<i>Hydrilla verticillata</i>	Hydrilla
<i>Hygrophila polysperma</i>	Hygrophila
<i>Ipomoea aquatica</i>	Water spinach
<i>Lagarosiphon major</i>	African elodea
Genus: <i>Limnophila</i>	Limnophila
<i>Lythrum salicaria</i>	Purple loosestrife
<i>Myriophyllum aquaticum</i>	Parrot-feather
<i>Myriophyllum spicatum</i>	Eurasian watermilfoil
<i>Najas marina</i>	Spinyleaf naiad
<i>Pistia stratiotes</i>	Water-lettuce
<i>Potamogeton crispus</i>	Curlleaf pondweed
<i>Salvinia molesta</i>	Giant salvinia
<i>Trapa natans</i>	Water chestnut

Source: Alabama Nonindigenous Aquatic Plant Control Act (1995, No. 95-767, p. 1813, §3)

Table 17. Prohibited Fish and Aquatic Mammal Species in Alabama

Scientific Name	Common Name
Fish of the genus <i>Clarias</i>	Walking catfish
Fish of the genus <i>Serrasalmus</i>	Piranha
Genus <i>Mylopharyngodon</i>	Black carp
<i>Siniperca spp.</i>	Chinese perch
<i>Channa maculata</i>	Channa
<i>Chirrhinus molitor</i>	Chirrhinus
<i>Alosa aestivalis</i>	Blueback herring
<i>Acipenser spp.</i> , except <i>A. oxyrinchus</i>	Non-native sturgeon
<i>Scardinius erythrophthalmus</i>	Rudd
<i>Rutilus rutilus</i>	Roach
<i>Myocastor coypus</i>	Nutria

Source: Alabama Regulations 220-2-.26 and 220-2-.93 (1999-2000)

7.6 State Level: Florida

Florida Fish and Wildlife Conservation Commission (FFWCC)

The FFWCC is charged with managing fish and wildlife resources for their long-term well-being and the benefit of people of Florida. Title XXCIII Natural Resources; Conservation, Reclamation, and Use, Chapter 370 Saltwater Fisheries, Florida Statutes (1999) provides authority regarding nonindigenous species and protection of Florida's living marine resources. According to § 370.081(2):

“It is unlawful to import or possess any marine plant or marine animal, not indigenous to the state, which ... may endanger or infect the marine resources of the state or pose a human health hazard ...”

This section provides a list of marine organisms that may not be imported (Table 18).

Table 18. Prohibited Marine Fish Species in Florida

Scientific Name	Common Name
Family Hydrophiidae	sea snakes
Family Trachinidae	weaverfishes
Genus <i>Synanceja</i>	stonefishes

Source: § 370-081(2), Florida Statutes (1999)

Title XXCIII Natural Resources; Conservation, Reclamation, and Use, Chapter 372 Freshwater Fish Dealer's License, Florida Statutes (1999), prohibits the importation of any exotic or nonindigenous fish without a fish sale license and fee payment through FFWCC (§ 372.65(1)) (note that this statute does not apply to persons or businesses with an aquaculture permit for the same species).

According to the FFWCC Code, Chapter 68A Freshwater Fish and Wildlife (68A-23.008):

“No person shall transport into the state, introduce, or possess for any purpose that might be reasonably expected to result in liberation into the waters of the state, any aquatic species not native to the state, without having secured a permit from the Commission ...”

Subject to specific conditions and adequate safeguards to prevent escape or accidental release, permits for restricted species (and their hybrids) are available for research or aquacultural purposes, commercial import or export facilities, or public aquaria involved in educational efforts. Permits are not issued for display in private aquaria. Facilities and all records (e.g., shipping tickets, invoices, bills of lading, or other records of sales, purchases, or transfers) are subject to periodic inspection by the FFWCC. Table 19 presents restricted freshwater species that may be possessed only under permit from the Executive Director of the FFWCC.

Table 19. Restricted Non-Native Freshwater Species in Florida

Scientific Name	Common Name
<i>Aristichthys nobilis</i>	Bighead carp
Family <i>Osteoglossidae</i> , all species except Silver arowana (<i>Osteoglossum bicirrhosum</i>)	Bony-tongue fishes
Genus <i>Salminus</i> , all species	Dorados
Family <i>Potamotrygonidae</i> , all species	Freshwater stingrays
<i>Ctenopharyngodon idella</i>	Grass carp *
Genus <i>Lates</i> , all species	Nile perches
<i>Hypophthalmichthys molitrix</i>	Silver carp
<i>Mylopharyngodon piceus</i>	Snail or black carp
<i>Tilapia (Oreochromis) aureus</i> , <i>T. (O.) hornorum</i> , <i>T. (O.) mossambicus</i> and <i>Tilapia (O.) niloticus</i>	Tilapia; <i>T. (O.) aureus</i> may be possessed, cultured, and transported without permit in the following areas: North Central Region, Citrus and Hernando counties only; Northeast Region, all counties, except Duval and Nassau; South and Southwest regions.
<i>Clarias batrachus</i>	Walking catfish
<i>Cherax quadricarinatus</i>	Australian red claw crayfish; tank culture systems only
<i>Ictalurus furcatus</i>	Blue catfish; except north and west of the Suwannee River blue catfish may be possessed without permit.
<i>Procambarus clarkii</i> and <i>P. zonangulus</i>	Red swamp crayfish and white river crayfish; except that pond aquaculture is prohibited; both species may be possessed west of the Apalachicola River or imported for direct sale to food wholesalers and food retailers for re-sale to consumers without permit.

Source: FFWCC Code, Chapter 68A Freshwater Fish and Wildlife (68A-23.008, F.A.C.)

* 68A-23.088, F.A.C. specifies detailed rules for possessing, stocking, selling, transferring, and transporting both triploid, and other than triploid (e.g., diploid), grass carp.

Several freshwater species (and their hybrids) are prohibited from import, sale, possession, or in-state transport. Table 20 presents the list of prohibited freshwater species in Florida. There are limited exceptions to this subsection that may be made by permit for viewing at large public aquaria or for research. However, no research or public aquaria permits shall be granted for piranhas and pirambeas (subfamily Serrasalminae, all species).

Department of Environmental Protection (FDEP)

Florida addresses nonindigenous aquatic plant species through two primary statutes, the Florida Aquatic Weed Control Act (FAWCA) and the Florida Nonindigenous Aquatic Plant Control Act (FNAPCA). FAWCA (Title XXCIII Natural Resources; Conservation, Reclamation, and Use, Chapter 369 Conservation, Part I Aquatic Plant Control, Section 369.20, Florida Statutes (1999)), provides FDEP authority to “direct the control, eradication, and regulation of noxious aquatic weeds and direct the research and planning” with the purpose of protecting human health, plant and animal life, and property. Under FAWCA, the FDEP Bureau of Invasive Plant Management (BIPM) coordinates and develops aquatic weed management programs in public waters, issues permits to control aquatic weeds in public waters, and disperses funds to agencies, local authorities, universities, or contractors for control and research activities.

Table 20. Prohibited Non-Native Freshwater Species in Florida

Scientific Name	Common Name
Family Malapteruridae, all species	African electric catfishes
Subfamily Hydrocyninae, all species	African tigerfishes
Family Clariidae, all species except <i>Clarias batrachus</i>	Airbreathing catfishes
Family Trichomycteridae, all species	Candiru catfishes
Family Electrophoridae, all species	Freshwater electric eels
Family Petromyzonidae, all species	Lampreys
Subfamily Serrasalminae, all species	Piranhas and pirambebas
Family Channidae, all species	Snakeheads
<i>Tilapia</i> , <i>Sarotherodon</i> and <i>Oreochromis</i> genera, all species except <i>Tilapia (Oreochromis) aurea</i> , <i>T. (O.) hornorum</i> , <i>T. (O.) mossambica</i> and <i>Tilapia (O.) nilotica</i>	Tilapias
Family Erythrinidae, all species	Trahiras or tigerfishes
Family Heteropneustidae, all species	Airsac catfishes
<i>Lepomis cyanellus</i>	Green sunfish
Genus <i>Cherax</i> , except for tank aquaculture of <i>Cherax quardricarinatus</i>	Australian crayfish
<i>Dreissena polymorpha</i>	Zebra mussels
Genus <i>Eriocheir</i> , or any part thereof.	Mitten crabs

Source: FFWCC Code, Chapter 68A Freshwater Fish and Wildlife (68A-23.008, F.A.C.)

Table 21. Prohibited Aquatic and Semi-Aquatic Plant Species in Florida

Scientific Name	Common Name	State Weed Status
<i>Alternanthera philoxeroides</i>	alligatorweed	Prohibited aquatic plant, Class 1
<i>Casuarina cunninghamiana</i>	river sheoak	Prohibited aquatic plant, Class 1
<i>Casuarina equisetifolia</i>	beach sheoak	Prohibited aquatic plant, Class 1
<i>Casuarina glauca</i>	gray sheoak	Prohibited aquatic plant, Class 1
<i>Casuarina lepidophloia</i>	belah	Prohibited aquatic plant, Class 1
<i>Crassula helmsii</i>	swamp stonecrop	Prohibited aquatic plant, Class 1
<i>Cupaniopsis anacardioides</i>	carrotwood	Noxious weed
<i>Dioscorea alata</i>	white yam	Noxious weed
<i>Dioscorea bulbifera</i>	air potato	Noxious weed
<i>Eichhornia azurea</i>	anchored waterhyacinth	Prohibited aquatic plant, Class 1
<i>Eichhornia crassipes</i>	common water hyacinth	Prohibited aquatic plant, Class 1
<i>Eichhornia diversifolia</i>	variableleaf water hyacinth	Prohibited aquatic plant, Class 1
<i>Eichhornia paniculata</i>	Brazilian water hyacinth	Prohibited aquatic plant, Class 1
<i>Hydrilla verticillata</i>	waterthyme	Prohibited aquatic plant, Class 1
<i>Hygrophila polysperma</i>	Indian swampweed	Prohibited aquatic plant, Class 2
<i>Imperata cylindrica</i>	cogongrass	Noxious weed
<i>Ipomoea aquatica</i>	swamp morning glory	Prohibited aquatic plant, Class 1
<i>Ipomoea fistulosa</i>	gloria de la manana	Prohibited aquatic plant, Class 1
<i>Lagarosiphon major</i>	African elodea	Prohibited aquatic plant, Class 1
<i>Limncharis flava</i>	Sawah-flowering rush	Prohibited aquatic plant, Class 1
<i>Limnophila sessiliflora</i>	Asian marshweed	Prohibited aquatic plant, Class 2
<i>Lygodium japonicum</i>	Japanese climbing fern	Noxious weed
<i>Lygodium microphyllum</i>	old world climbing fern	Noxious weed
<i>Lythrum salicaria</i>	purple loosestrife	Prohibited aquatic plant, Class 1
<i>Melaleuca quinquenervia</i>	punktree	Prohibited aquatic plant, Class 1

Scientific Name	Common Name	State Weed Status
<i>Mimosa pigra</i>	black mimosa	Prohibited aquatic plant, Class 1
<i>Monochoria hastata</i>	arrowleaf falsepickerelweed	Prohibited aquatic plant, Class 1
<i>Monochoria vaginalis</i>	heartshape falsepickerelweed	Prohibited aquatic plant, Class 1
<i>Myriophyllum spicatum</i>	Eurasian watermilfoil	Prohibited aquatic plant, Class 1
<i>Nechamandra alternifolia</i>	none provided	Prohibited aquatic plant, Class 1
<i>Oryza rufipogon</i>	brownbeard rice	Prohibited aquatic plant, Class 1
<i>Paederia foetida</i>	skunk vine	Noxious weed
<i>Pennisetum polystachyon</i>	missiongrass, thin napiergrass	Noxious weed
<i>Pistia stratiotes</i>	water lettuce	Prohibited aquatic plant, Class 2
<i>Pontederia rotundifolia</i>	tropical pickerelweed	Prohibited aquatic plant, Class 1
<i>Pueraria montana</i>	kudzu	Noxious weed
<i>Salvinia auriculata</i>	eared watermoss	Prohibited aquatic plant, Class 1
<i>Salvinia biloba</i>	giant salvinia	Prohibited aquatic plant, Class 1
<i>Salvinia herzogii</i>	giant salvinia	Prohibited aquatic plant, Class 1
<i>Salvinia molesta</i>	aquarium watermoss	Prohibited aquatic plant, Class 1
<i>Salvinia natans</i>	eared watermoss	Prohibited aquatic plant, Class 1
<i>Sapium sebiferum</i>	Chinese tallow tree	Noxious weed
<i>Schinus terebinthifolius</i>	peppertree	Prohibited aquatic plant, Class 1
<i>Solanum tampicense</i>	wetland nightshade	Noxious weed
<i>Sparganium erectum</i>	simplestem bur-reed	Prohibited aquatic plant, Class 1
<i>Stratiotes aloides</i>	water soldiers	Prohibited aquatic plant, Class 1
<i>Trapa bicornis</i>	horn nut	Prohibited aquatic plant, Class 1
<i>Trapa natans</i>	water chestnut	Prohibited aquatic plant, Class 1
<i>Trapa natans</i>	singhara nut	Prohibited aquatic plant, Class 1
<i>Trapa natans</i>	caltrop	Prohibited aquatic plant, Class 1
<i>Vossia cuspidata</i>	hippo grass	Prohibited aquatic plant, Class 1

Source: Rules of FDEP, Chapter 62C-52.011 – Prohibited Aquatic Plants, and rules of FDACS, Chapter 5B-57 – Introduction or Release of Plant Pests, Noxious Weeds, Arthropods, and Biological Control Agents (those listed in the table as “Noxious weed”).

Class 1 - Plants that may not be possessed, collected, transported, cultivated, or imported without a special permit.

Class 2 - Plants that can be cultured in-state for out-of-state sales only, but may not be imported or collected from the wild.

The FNAPCA (Title XXCIII Natural Resources; Conservation, Reclamation, and Use, Chapter 369 Conservation, Part I Aquatic Plant Control, Section 369.22, Florida Statutes (1999)) provides FDEP authority to supervise the control of any “floating, submersed, or ditch bank species, growing in, or closely associated with, an aquatic environment.” The statute has provisions for FDEP to permit importing, transporting, cultivating, collecting, selling, or possessing any aquatic plant on the prohibited plant species list. This list, cooperatively developed by the FDEP and the Florida Exotic Pest Plant Council (Schardt, pers. comm.) is presented in Table 21. Under this statute, BIPM issues permits to control, eradicate, remove or alter any nonindigenous aquatic plants in public waters. The Invasive Plant Control Trust Fund (§ 369.252(4)) provides resources for plant control activities on public lands and public waters (Fletcher 2000).

The BIPM has three sections. The Aquatic Plant Management Section (APMS) currently manages the control of 11 invasive aquatic plants in Florida’s 1.3 million acres of public waters: hydrilla, water hyacinth, water lettuce, aquatic nightshade, giant salvinia, hygrophilia, paragrass,

torpedograss, waterspinach, West Indian marshgrass, and wild taro (FDEP 2000). The APMS primarily disperses funds to private contractors for regular control of high priority species. The APMS budget was increased from approximately \$10 million to \$25 million for FY 2001 (Schardt, pers. comm.). The Upland Plant Management Section similarly manages the control of several semi-aquatic, ditchbank species. The Field Operations Section permits importation and collection activities, and routinely examines retail facilities for prohibited species. The BIPM has a Weed Alert program to disseminate identification information to agencies, local authorities, universities, or contractors conducting control activities around the state.

Florida Department of Agriculture and Consumer Services (FDACS)

The FDACS has promulgated rules (Chapter 5B-57) under the authority of § 570.07 (13), (23), Florida Statutes, to control the introduction into, or movement or spread within this state of any plant pest, noxious weed or arthropod, and to establish procedures under which the field release of plant pests, noxious weeds, arthropods, and biological control agents are permitted. Table 21 includes terrestrial weed species in these rules that readily grow in semi-aquatic and ditchbank habitats.

The FDACS regulates aquaculture activities under Title XXXV Agriculture, Horticulture, and Animal Industry, Chapter 597 Aquaculture, Florida Statutes (1999). A permit is required for raising or possessing nonindigenous species for aquaculture purposes. Florida has a very restrictive stocking policy, which prohibits the stocking of any species that is not native; however this policy does not apply to marine bivalve mollusks, which are transported throughout the state without regulatory restrictions.

Florida also mandates specific requirements for outdoor facilities that hold prohibited aquatic species. The primary requirement is that a surrounding levee must be at least one foot above the 100-year flood level, have either no water discharge or a barrier system adequate to prevent escape of any life stage, and be inaccessible to the public. Though the 100-year floodplain was often cited by other review participants as an appropriate restriction, the important aspects of Florida's requirements are not its specific requirements so much as its clear recognition of the importance of effective containment.

Florida Exotic Pest Plant Council (FLEPPC)

The FLEPPC's goals are to build public awareness about the serious threat invasive plants pose to native ecosystems, secure funding and support for control and management of exotic plants, and develop integrated management and control methods to prevent the spread of exotic pest plants throughout the Florida. FLEPPC and FDEP coordinate closely to manage nonindigenous aquatic plant species control programs.

7.7 State Level: Louisiana

Title 56, Section 319, Louisiana Revised Statutes, provides the Louisiana Wildlife and Fisheries Commission (LFWC) with the authority to control the importation, sale, transport, and possession of specified nonindigenous fish species. Table 22 lists the species prohibited in this statute, however the LFWC has the authority to issue renewable, one-year permits for the possession of these species (actual permitting is conducted for the LFWC by the Louisiana Department of Wildlife and Fisheries (LDWF)). Title 56, Section 17 gives the Director of the LFWC the authority to introduce, or issue permits for such introductions, any kind of fish into any waters, for the purposes of science and of cultivation and distribution. Title 76, Section 901, Wildlife and Fisheries regulations, addresses LDWF permits for the possession and transportation of triploid grass carp for aquatic plant control. Section 903 outlines regulations for tilapia aquaculture.

Title 56, Section 328, Louisiana Revised Statutes, provides the LWFC with the authority to prohibit the importation of specified “noxious aquatic plants,” to protect fish habitat. Table 23 lists aquatic plant species prohibited under this statute. The LWFC can issue permits for importation of these species for the purpose of conducting scientific investigations.

Title 33, Section 1791, Revised Louisiana Statutes, provides the Louisiana Department of Agriculture and Forestry (LDAF) with the authority to regulate terrestrial plant introductions, and lists the Chinese tallow tree (*Sapium sebiferum*), a species that readily grows in aquatic ecosystems, as a noxious weed. LDAF periodically inspects nurseries for prohibited nonindigenous species, both terrestrial and aquatic. The weak statute that provides LDAF with this authority only prohibits importation into the state, and once these organisms are in the state, there is no authority to regulate within-state distribution (Brassette, pers. comm.). Infestations of public waterbodies and other occurrences that cause citizen complaints become the responsibility of the LDWF Aquatic Plant Control Section (APCS).

Table 22. Prohibited Fish Species in Louisiana

Scientific Name	Common Name
<i>Carassius auratus</i>	goldfish
<i>Cichlasoma cyanoguttatum</i>	Rio Grande tetra
<i>Clarias batrachus</i>	carnero catfish
All of the family Clariidae	walking catfishes
<i>Cyprinus carpio</i>	common carp
<i>Electrophorus sp.</i>	freshwater electric eel
<i>Scardinius erythrophthalmus</i>	rudd
Fish of the genus <i>Serrasalmus</i>	piranha
many	carp
many	all species of tilapia

Source: Louisiana Revised Statutes, Title 56, §319.

Table 23. Prohibited Aquatic Plant Species in Louisiana

Scientific Name	Common Name
<i>Elodea canadensis</i>	elodea
<i>Eichhornia azurea</i>	rooting or anchoring waterhyacinth
<i>Eichhornia crassipes</i>	waterhyacinth
<i>Hydrilla spp.</i>	hydrilla
<i>Lagarosiphon major</i> and <i>L. muscoides</i>	African elodea
<i>Lythrum salicaria</i>	purple loosestrife
<i>Melaleuca auinquenvia</i>	kapok tree
<i>Myriophyllum spicatum</i>	Eurasian watermilfoil
<i>Najas marina</i>	marine naiad
<i>Najas minor</i>	slender naiad
<i>Panicum repens</i>	torpedograss
<i>Pistia stratiotes</i>	water lettuce
<i>Pontederia spp.</i>	pickerelweed
<i>Salvinia spp.</i>	salvinia
<i>Spirodela oligorrhiza</i>	giant duckweed
<i>Trapa spp.</i>	waterchestnut

Source: Louisiana Revised Statutes, Title 56, §328.

The APCS is primarily funded to control water hyacinth infestations statewide, with the purpose of maintaining boat access and improving habitat, but APCS is underfunded to complete this task (Brassette, pers. comm.). Extensive hydrilla (*Hydrilla verticillata*) and common salvinia (*Salvinia minima*) infestations often go unaddressed due to funding shortages (there is no statewide funding to control hydrilla and the APCS has received only one allocation of funding to assess and control common salvinia (Brassette, pers. comm.)). Common salvinia infestations can seriously impact duck hunting: when the common salvinia infestation brown in the fall, ducks appear to avoid landing in these brown patches. Governor Mike Foster recently established May 23 as Salvinia Awareness Day for Louisiana, and LDWF convened an ongoing Giant Salvinia Task Force in 2000.

7.8 State Level: Mississippi

Passed in 1998, Title 49 Conservation and Ecology (Mississippi Code Annotated §49-7-80 (1972 & Supp. 1999)) contains Mississippi's nonindigenous species provisions (Fletcher 2000). Authority is given to the Mississippi Department of Wildlife, Fisheries, and Parks (MDWFP) to establish and maintain a list of approved, restricted, and prohibited nonindigenous species, and to establish rules governing their importation, possession, sale, and escape. Tables 24, 25, and 26 list the nonindigenous fish, invertebrate, and aquatic plant species prohibited by MDWFP.

Title 49 prohibits stocking or releasing “any animal not indigenous to Mississippi” without a permit from MDWFP. Where applications are made to release nonindigenous species, MDWFP must “determine any detrimental effect the species might have on the environment.”

Table 24. List of Prohibited Fish Species in Mississippi

Scientific Name	Common Name
Family Petromyzontidae (includes sea lamprey)	Lampreys
Subfamily Serrasalminae (includes all piranhas)	Piranha and pirambebas (all species)
<i>Astyanax fasciatus</i>	Banded tetra
<i>Astyanax mexicanus</i>	Mexican tetra or Silvery tetra
<i>Hoplias malabaricus</i>	Tiger characin or trahira
<i>Raphidon vulpinus</i>	Skinny Tiger characin or biara
Family Trichomycteridae	Pencil or parasitic catfishes
Family Clariidae	Airbreathing or Walking catfishes
Family Osteoglossidae	Bony-tongue fishes
Genus <i>Salminus</i>	Dorados
Family Potamotrygonidae	Freshwater stingrays
Genera <i>Lates</i> and <i>Luciolates</i>	Nile perches
Family Malapteruridae	African electric catfishes
Family Alestidae, Subfamily Hydrocyninae	African tigerfishes
Family <u>Electrophoridae</u>	Freshwater electric eels
Family Channidae	Snakeheads
Family Erythrinidae	South American tigerfishes
Family Heteropneustidae	Airsac catfishes
<i>Cichla ocellaris</i>	Peacock bass or Peacock cycled
Family Characidae, all species of the Genus <i>Acestrorhynchus</i> ; Family Ctenolucidae, all species of the Genera <i>Ctenolucius</i> and <i>Luciocharax</i> (<i>Boulengerella</i>)	South American pike characoids
Family Hepsetidae, all species of the Genus <i>Hepsetus</i> Family Ichthyboridae, all species	African Pike characoids
Family Characidae, Subfamily Rhamphodontinae, all species of the Genera, <i>Hydrolycus</i> and <i>Raphiodon</i> (<i>Cynodon</i>)	Rhamphodontid characoids
<i>Gymnotus carapo</i>	Banded knifefish
Family Cyprinidae, all species of the Genera <i>Cirrhinus</i> and <i>Thynnichthys</i>	Mud carp, Sandhkol carp
Family Cyprinidae, all species of the Genera <i>Scardinius</i> and <i>Rutilus</i>	Rudd and Roach
Family Cyprinidae, all species of the Genera <i>Abramis</i> , <i>Blicca</i> , <i>Megalobrama</i> and <i>Parabramis</i>	Old World breams
Family Cyprinidae, all species of the Genus <i>Leuciscus</i>	Old World chubs; ide and dace
Family Cyprinidae, all species of the Genera <i>Aspius</i> , <i>Psedaspius</i> , <i>Aspiolucius</i> , and <i>Elopichthys</i>	Asps and yellowcheek
Family Cyprinidae, all species of the Genus <i>Tor</i> and the species <i>Barbustor</i> and <i>Barbus hexagonolepis</i>	Giant Barbs and Mahseers
Family Cyprinidae, all species of the Genus <i>Catla</i>	Catla
Family Cetopsidae, all species	Whale catfishes
Family Poeciliidae, <i>Bilonesox belizanus</i>	Pike killifish
Family Synanceiidae, all species	Marine stonefishes
Family Percidae, all species of the Genus <i>Gymnocephalus</i>	Ruffes and Schraetzers
Family Percidae, <i>Stizostedion lucioperca</i> , <i>Stizostedion volgensis</i> (<i>volgensis</i>), <i>Stizostedion marinum</i>	Zanders
Family Cichlidae, all species of the Genera <i>Crenicichla</i> and <i>Batrachops</i>	Pike cichlids
Family Luciocephalus, all species	Asian pikehead

Source: Van Devender (2000)

Table 25. List of Prohibited Invertebrate Species (Mussels and Crayfishes) in Mississippi

Scientific Name	Common Name
<i>Cherax destructor</i>	Yabbie Lobster
<i>Dreissena polymorpha</i>	Zebra Mussel
All species of the Genus <i>Astacopsis</i>	Tasmanian Giant crayfish

Source: Van Devender (2000)

Table 26. List of Prohibited Aquatic Plant Species in Mississippi

Scientific Name	Common Name
<i>Hydrilla verticillata</i>	Hydrilla (Florida elodea)
<i>Egeria densa</i>	Egeria (African elodea)
<i>Eichhornia crassipes</i>	Water hyacinth *
<i>Eichhornia azurea</i>	Rooted hyacinth
<i>Myriophyllum spicatum</i>	Eurasian watermilfoil
<i>Pistia stratiotes</i>	Water lettuce
<i>Melaleuca quinquenervia</i>	Paperbark (melaleuca)

Source: Van Devender (2000)

* Use of water hyacinth in a controlled, filtered aquaculture system may be allowed.

Mississippi's Aquaculture Act (Mississippi Code Annotated §79-22-9 (1972 & Supp. 1999) was passed in 1988, primarily to protect and aid the state's farm-raised catfish industry (Van Devender 2000). Most provisions of the act, including issuance of aquaculture cultivation and marketing permits, are administered by the Mississippi Department of Agriculture and Commerce (MDAC). Cultivation permits for any nonindigenous species are required, with certain exceptions, for example, no permit is required for nonindigenous tropical fish that are maintained in closed systems. The Aquaculture Task Force (ATF), established in the Aquaculture Act, is charged with advising the MDAC in its permit issuance responsibilities. The Mississippi Department of Marine Resources (MDMR) is one member of the ATF (Van Devender 2000). Section 79-22-15(4), Mississippi Code of 1972 states:

"The Department of Wildlife, Fisheries and Parks may promulgate regulations which specify criteria to protect marine resources and to prevent the release of undesirable species from an aquaculture facility into the environment ..."

Given that MDMR has authority for regulating, and technical expertise, in marine fisheries, MDMR would assist MDWFP in any regulation development.

The State of Mississippi is currently taking initial steps to form a state-level Exotic Pest Plant Council (Holland, pers. comm., Matlack 2000).

7.9 State Level: Texas

Under existing Parks and Wildlife Code (Texas Parks & Wildlife Code § 66.007), the Texas Parks and Wildlife Commission (TPWC) has authority to prevent the importation, possession, sale, or introduction into state waters of exotic, harmful, or potentially harmful fish, shellfish, or aquatic plants, except as authorized by rule or permit issued by the Texas Parks and Wildlife Department (TPWD). Table 27 lists the fish and shellfish species, and Table 28 lists the aquatic plant species, restricted by TPWC. TPWD issues Exotic Species Permits for these restricted species for a variety of situations, for example: (1) as experimental organisms in a TPWD-approved research program; (2) for exhibit in a public aquarium approved for display of harmful or potentially harmful exotic fish, shellfish, and aquatic plants; and (3) fish farming operations (TPWD Fisheries Regulations § 57.113). A fish farmer who holds a valid Exotic Species Permit may “possess, propagate, transport, or sell Pacific white shrimp (*Penaeus vannamei*) provided the exotic shellfish meet disease free certification requirements” (TPWD Fisheries Regulations § 57.113). The statute in § 66.007 provides the authority to require similar certification for other farmed exotic shellfish species. The Texas Aquaculture Code (Texas Agricultural Code § 134.001) provides authority to control the importation, possession, propagation, and sale of harmful and potentially harmful exotic species by an aquaculturalist to the TPWC (Fletcher 2000).

The State of Texas historically has promoted introductions of nonindigenous species to enhance hunting and fishing opportunities. That perspective has changed dramatically and exotic introductions are now viewed as potentially problematic, however the system remains permissive rather than restrictive (McKinney 2000). The current regulatory structure is under review and will likely be revised to reflect new perspectives on exotic introductions and to a lesser degree all nonindigenous species (McKinney 2000). In a state as diverse as Texas, intrastate movement of species, for example, from one river basin to another, can cause problems normally associated with exotic species: the political boundaries of the state mean nothing in this context (McKinney 2000).

Table 27. List of Prohibited Fish and Shellfish Species in Texas

Common Name	Family	Species Affected
Freshwater Eels	Anguillidae	All species except <i>Anguilla rostrata</i>
Swamp Eels	Synbranchidae	All species
Lampreys	Petromyzontidae	All species except <i>Ichthyomyzon castaneus</i> and <i>I. qaqei</i>
Freshwater Stingrays	Potamotrygonidae	All species
Araima	Osteoglossidae	<i>Arapaima gigas</i>
South American Pike	subfamily: Characoids	All species of genus <i>Acestrorhynchus</i>
African Tiger Fish	subfamily: Hydrocyninae	All species
Piranhas and Priambebus	subfamily: Serrasalminae	All species
Rhaphiodontid	subfamily: Rhaphiodontinae	All species of genera <i>Hydrolycus</i> and <i>Rhaphiodon</i> (synonymous with <i>Cynodon</i>)
Dourados	subfamily: Bryconinae	All species of genus <i>Salminus</i>
South American Tiger Fishes	Erythrinidae	All species

Common Name	Family	Species Affected
South American Pike	Ctenolucidae	All species of genera <i>Ctenolucius</i> and <i>Luciocharax</i> (synonymous with <i>Boulengerella</i> and <i>Hydrocinus</i>)
African Pike Characoids	Hepsetidae & Ichthyboridae	All species
Electric Eels	Electrophoridae	<i>Electrophorus electricus</i>
Carp and Minnows	Cyprinidae	All species and hybrid of species of genera: <i>Abramis</i> , <i>Aristichthys</i> , <i>Aspius</i> , <i>Aspiolucius</i> , <i>Blicca</i> , <i>Catla</i> , <i>Cirrhina</i> , <i>Ctenopharyngodon</i> , <i>Elopichthys</i> , <i>Hypophthalmichthys</i> , <i>Leuciscus</i> , <i>Megalobrama</i> , <i>Mylopharyngodon</i> , <i>Parabramis</i> , <i>Pseudaspius</i> , <i>Rutiluc</i> , <i>Scardinius</i> , <i>Thynnichthys</i> , <i>Tor</i> , and the species <i>Barbustor</i> (synonymous with <i>Barbus hexoagoniolepis</i>)
Walking Catfish	Claridae	All species
Electric Catfish	Malapteruridae	All species
South American Parasitic Candirus Catfish	subfamilies: Stegophilinae & Vandelliinae	All species
Pike Killifish	Poeciliidae	<i>Belonesox belizanus</i>
Marine stonefishes	Synanceiidae	All species
Tilapia	Cichlidae	All species of genus <i>Tilapia</i> and <i>Oreochromis</i>
Asian Pikeheads	Luciocephalidae	All species
Snakeheads	Channidae	All species
Walleye	Percidae	All species except of the genus <i>Stizostedion</i> except <i>Stizostedion vitreum</i> and <i>S. canadense</i>
Nile perch	Centropomidae	All species of genera <i>Lates</i> and <i>Luciolates</i>
Drums	Sciaenidae	All species of genus <i>Cynoscion</i> except <i>Cynoscion nebulosus</i> , <i>C. nothus</i> , and <i>C. arenarius</i>
Whale Catfish	Cetopsidae	All species
Ruff	Percidae	All species of genus <i>Gymnocephalus</i>
Air sac Catfish	Heteropneustidae	All species of genus <i>Heteropneustes</i>
Crayfishes	Parastacidae	all species of genus <i>Astracopsis</i>
Giant Ram's-horn Snails	Piliidae	all species of genus <i>Marisa</i>
Zebra Mussels	Dreissenidae	all species of genus <i>Dreissena</i>

Source: TPWD website (<http://www.tpwd.state.tx.us/fish/infish/regulate/exotics.htm>), accessed in May 2000.

In 1999, the Texas Legislature enacted legislation that directs TPWD, in coordination with the Texas Natural Resources Conservation Commission, the Texas Department of Agriculture, and water districts, to develop and adopt a Statewide Aquatic Vegetation Management Plan (Act of June 19, 1999, ch. 1461, 1999 Tex. Sess. Law Serv. 12 (West 1999)) (Fletcher 2000). The legislation provides the TPWD oversight in aquatic vegetation management and focuses on integrated pest management strategies (Parks and Wildlife Code § 11.081). The Texas Parks and Wildlife Commission will adopt rules implementing the statutes in June 2000.

TPWD staff have been active participants in Western Regional Panel activities. The Western Regional Panel has been an effective advocate in many issues relating to nonindigenous aquatic species, particularly in ballast water management, zebra mussel research, Chinese mitten crab control, and green crab research.

Table 28. List of Prohibited Aquatic Plant Species in Texas

Common Name	Family	Species Affected
Giant Duckweed	<i>Lemnaceae</i>	<i>Spirodela oligorhiza</i>
Salvinia	<i>Salviniaceae</i>	all species of genus <i>Salvinia</i>
Waterhyacinth	<i>Pontederiaceae</i>	<i>Eichhornia crassipes</i>
Waterlettuce	<i>Araceae</i>	<i>Pistis stratiotes</i>
Hydrilla	<i>Hydrocharitaceae</i>	<i>Hydrilla verticillata</i>
Lagarosiphon	<i>Hydrocharitaceae</i>	<i>Lagarosiphon major</i>
Eurasian Watermilfoil	<i>Haloragaceae</i>	<i>Myriophyllum spicatum</i>
Alligatorweed	<i>Amaranthaceae</i>	<i>Alternanthera philoxeroides</i>
Rooted Waterhyacinth	<i>Pontedericiaceae</i>	<i>Eichhornia azurea</i>
Paperbark	<i>Myrtaceae</i>	<i>Melaleuca quinquenervia</i>
Torpedograss	<i>Gramineae</i>	<i>Panicum repens</i>
Water Spinach	<i>Convolvulaceae</i>	<i>Ipomoea aquatic</i>

Source: TPWD website (<http://www.tpwd.state.tx.us/fish/infish/regulate/exotics.htm>), accessed in May 2000.

7.10 Federal and Gulf State Agency Costs for Aquatic Invasive Species Management and Control

Federal Agency Expenditures

The U.S. General Accounting Office (GAO) recently surveyed ten federal departments to determine national expenditures on invasive species activities (both terrestrial and aquatic). Eight agencies on the Invasive Species Council – representing the Departments of Agriculture, Commerce, Defense, Interior, State, Treasury, and Transportation, and the Environmental Protection Agency – as well as the Smithsonian Institute and the National Science Foundation, collectively spent \$513.9 million in fiscal year 1999 and \$631.5 million in fiscal year 2000 to management and control invasive species (GAO 2000). The Department of Agriculture spent 89 percent of this funding (GAO 2000). Prevention of the introduction of invasive species received the largest percentage of funding – about 51 percent and 49 percent in fiscal years 1999 and 2000, respectively (GAO 2000).

The GAO also surveyed seven states – California, Florida, Hawaii, Idaho, Maryland, Michigan, and New York – to determine selected state expenditures on invasive species activities. Florida spent the most at \$ 94.5 million and \$ 127.6 million in 1999 and 2000, respectively, on managing and controlling invasive terrestrial and aquatic species (GAO 2000). California reported the second highest expenditures at \$ 82.6 million and \$ 87.2 million in 1999 and 2000, respectively (GAO 2000).

Alabama

The Alabama Division of Wildlife and Freshwater Fisheries spent approximately \$ 30,000 in fiscal year 2000 to manage invasive plant species in freshwater systems (Zolcynski, pers.

comm.). The Tennessee Valley Authority and the Alabama Power Company also manage programs to control invasive freshwater species in Alabama. There are currently no programs within Alabama state agencies devoted to the management of invasive species in marine systems (Minton, pers. comm.).

Florida

The GAO reported that Florida state agencies spent \$ 94.5 million and \$ 127.6 million in 1999 and 2000, respectively, on managing terrestrial and aquatic invasive species (GAO 2000). The FDEP, Southwest Florida Water Management District (WMD), South Florida WMD, and the St. Johns River WMD spent approximately \$23.7 million on invasive aquatic plant management (see Table 29). The Aquatic Plant Management Section within FDEP currently manages the control 11 invasive aquatic plants in Florida's 1.3 million acres of public waters: hydrilla, water hyacinth, water lettuce, aquatic nightshade, giant salvinia, hygrophila, paragrass, torpedograss, waterspinach, West Indian marshgrass, and wild taro (FDEP 2000). The APMS budget was increased from approximately \$10 million to \$25 million for FY 2001 (FDEP 2000). The APMS primarily disperses funds to private contractors for regular control of high priority species. The Marine Fisheries Division of the FFWCC spent approximately \$2 million in fiscal year 1999 (Table 29) for the control of invasive fish and aquatic invertebrates.

Louisiana

The LDWF Aquatic Plant Control Section, and the USACE together spent \$ 1.5 million dollars in fiscal year 2000 to manage invasive aquatic plant species in Louisiana (Brassette, pers. comm. and Cali, pers. comm.). The USACE specified that 60 percent of those funds were spent on actual contractor activities (i.e., plant removal, clearing waterways) and the remaining 40 percent of the funds were spent on program management. There are no programs devoted to management of invasive fish or aquatic invertebrates (Bigger, pers. comm.).

Mississippi

There are no programs within Mississippi state agencies entirely dedicated to management and control of aquatic invasive species (Van Devender, pers. comm.). The Mississippi Department of Marine Resources does administer a monitoring program for red tide, which is conducted for the National Shellfish Sanitation Program. The program includes aerial flights and water sampling costing approximately \$ 25,000 to \$ 50,000 per year (Van Devender, pers. comm.). There are currently no comprehensive state agency efforts to control invasive freshwater plants (Van Devender, pers. comm.).

Texas

The TPWD Aquatic Vegetative Control Group spent approximately \$ 750,000 per year on invasive aquatic plant management in the mid to late 1980s (Helton, pers. comm.). There is currently a proposal for a \$ 1.5 to \$ 2 million budget to continue management of these plant species, such as giant salvinia, hydrilla, water hyacinth, alligator weed, water lettuce, and Eurasian milfoil (Helton, pers. comm.).

Table 29. Fiscal Year 1999 Expenditures by Florida State Agencies for Invasive Species Management and Control Activities

Agency	Species Group	Itemized FY99 Expenditures	Total FY99 Expenditures
Florida Department of Environmental Protection	Plants <ul style="list-style-type: none"> • Terrestrial non-crop • Aquatic 	\$ 2 million \$ 17.3 million	\$19.3 million
Florida Fish and Wildlife Conservation Commission	Fish and aquatic invertebrates Terrestrial arthropods	\$2,001,000 \$100,000	\$2,101,000
Northwest Florida WMD	Plants <ul style="list-style-type: none"> • Terrestrial non-crop 	\$13,320	\$13,320
Southwest Florida WMD	Plants <ul style="list-style-type: none"> • Terrestrial non-crop • Aquatic Mammals Expenditures that cut across or cover more than one type of invasive species	\$185,765 \$48,185 \$12,889 \$150,043	\$396, 882
South Florida WMD	Plants <ul style="list-style-type: none"> • Terrestrial non-crop • Aquatic 	\$3,154,587 \$5,689,805	\$8,844,392
St. Johns River WMD	Plants <ul style="list-style-type: none"> • Terrestrial non-crop • Terrestrial crop • Aquatic Mammals	\$409,600 \$5,000 \$614,400 \$229,675	\$1,258,675
Suwannee River WMD	Plants <ul style="list-style-type: none"> • Terrestrial non-crop 	\$25,500	\$25,500
Florida Department of Agriculture	Animal/Plant Microorganisms and Diseases Plants <ul style="list-style-type: none"> • Terrestrial non-crop • Terrestrial crop Terrestrial arthropods Expenditures that cut across or cover more than one type of invasive species	\$23,965,920 \$11, 409, 768 \$370,000 \$9,409,667 \$741, 556	\$45,896,911
Florida Department of Transportation	Plants <ul style="list-style-type: none"> • Terrestrial non-crop 	\$13 million	\$13 million

Source: Florida Governor's Office (1999).

WMD = Water Management District

7.11 Private Organizations

The Nature Conservancy (TNC)

Founded in 1951, TNC is a leading private conservation organization. The mission of TNC is to preserve plants, animals, and natural communities that represent the diversity of life on Earth by protecting the lands and waters they need to survive. Conservancy resources are used to purchase or otherwise protect habitats that maintain endangered or threatened species and significant biological communities. Part of this management responsibility includes protecting preserves from nonindigenous species invasions.

TNC maintains and manages a number of preserves in the Gulf of Mexico region. There are four preserves in Alabama (Bibb County Glades, Grand Bay Savanna, Chitwood Barrens Preserve, Pratt's Ferry-Cahaba River, and Desoto Woods); ten in Florida (Rock Hill Preserve, Apalachicola Bluffs & Ravines Preserve, John S. Phipps Preserve, Janet Butterfield Brooks Preserve, Tiger Creek Preserve, The Disney Wilderness Preserve, Saddle Blanket Lakes Preserve, Blowing Rocks Preserve, Torchwood Hammock Preserve, and Terrestris); four in Louisiana (Cypress Island Preserve, Lake Ramsay Wetland Preserve, Mary Ann Brown Preserve, and White Kitchen Preserve); three in Mississippi (Charles M. Deaton Nature Preserve, Grand Bay Savanna, and Coonewah Creek Chalk Bluffs Preserve); and 35 in Texas (Wier Woods, Wilson Preserve, Roy E. Larsen Sandyland Sanctuary, Big Thicket Bogs & Pinelands, Little Rocky, Hookwood Preserve, North Boggy Slough, Sheff's Woods, Caddo Lake, Oak Woods and Prairies, Lennox Woods, Blackland Prairies, Tridens Prairie, Clymer Meadow, County Line Prairie, Matthews Prairie, Leonhardt Prairie, Rolling Plains, High Plains, Enron Matagorda Island Environmental Education and Research Center, Texas City Prairie Preserve, Pierce Marsh, Clive Runnells Family Mad Island Marsh Preserve, Shamrock Island, Redhead Pond, High Island, Mesquite Brushland, Chihuahua Woods, Eckert James River Bat Cave, Ruth P. M. Lehmann Preserve, Barton Creeek Habitat Preserve, Ezell's Cave, Elizabeth P. Hill Preserve, Gypsum Dunes, Madera Canyon Ranch, Davis Mountains Preserve, Sandia Springs, Diamond Y Spring Preserve, Brushy Canyon, Chandler Independence Creek, Dolan Falls Ranch, Cuatro Cienegas National Wildlife Refuge, Laguna Madre, and Sierra Madre Oriental).

Florida Native Plant Society (FNPS)

The FNPS was organized in 1980 to promote the preservation, conservation, and restoration of the native plants and native plant communities of Florida. The FNPS represents the interest of individuals and organizations working towards the preservation, conservation, and restoration of the native plants and plant communities of Florida. Education and conservation are the primary goals of the FNPS.

Louisiana Wildlife Federation (LWF)

At the March 12, 200 meeting in Alexandria, Louisiana, the Louisiana Wildlife Federation adopted a resolution on controlling invasions of exotic fish species. It states that:

- Louisiana has been and continues to be invaded by exotic fish species released in other states; recent examples include grass carp, bighead carp, and silver carp.
- Two of Louisiana's sister states have legalized the introduction of exotic black carp, a species that will eventually invade Louisiana waters.
- Invasion and establishment of exotic aquatic species is often detrimental to native species and their habitats.
- Introduction and invasion of exotic aquatic species into Louisiana waters should be curtailed and the pathways of invasion closed.
- Preventative action should begin now at the regional, state, and local levels.

The statement resolves that the LWF urges and requests the National Nuisance Species Task Force and the Invasive Species Council to form an interstate organization composed of states with common watersheds and river basins, and that the states prepare a cooperative plan addressing the release, control, and management of exotic species.

7.12 International Level: Reference to Information

The Invasive Species Council has produced an excellent reference on the federal and international management framework for nonindigenous species, *United States Invasive Species Draft Management Plan: Preparing for the Future* (ISC 2000). While currently in its first draft stage, Appendix 3, International Legal Instruments With Programs/ Activities Pertaining to Invasive Species, and Appendix 4, Codes of Conduct/Guidelines Pertaining to Invasive Species, should serve as excellent references and will not be re-presented in this report. However, one organization is highlighted below.

North American Council on Environmental Cooperation (CEC)

The CEC is an international organization created by Canada, Mexico and the U.S. under the North American Agreement on Environmental Cooperation. The CEC was established to address regional environmental concerns, help prevent potential trade and environmental conflicts, and to promote the effective enforcement of environmental law. The Agreement complements the environmental provisions of North American Free Trade Agreement.

One of the CEC's program areas is Conservation of Biodiversity. The mission of work in this program area is to promote cooperation between Canada, Mexico and the U.S. in fostering conservation, sound management and sustainable use of North American biodiversity. The "Cooperation on the Protection of Marine and Coastal Ecosystems" project has the objective of protecting marine and aquatic ecosystems from the effects of land-based human activity and aquatic invasive species. Effort on this project is divided into two initiatives, one of which is Closing the Pathways of Aquatic Invasive Species Across North America.

8.0 An Inventory of Regional Actions

"Eradication of an established invader is rare."

(Mack et al. 2000)

An inventory of actions, projects, and initiatives to address aquatic invasive species issues in each Gulf State, and across the Gulf of Mexico region, was developed. The inventory, presented in Appendix H, is not meant to be comprehensive, rather, it is intended to be a representative listing of recent major actions (with a focus on 1997 to present). The purpose of the inventory is to facilitate Gulf-region coordination and communication on the issues and methods to address the issues.

Actions included in the inventory were compiled by interviewing ISFT members and other Gulf-region invasive species managers, and searching the Internet. The inventory is loosely organized by actions taking place at the regional level and within each of the five Gulf states. Contact information is provided where available. The types of actions included in the inventory are:

- New species detection and taxonomic, life history, and biological descriptions
- Monitoring species distribution and rates of spread
- Developing and applying control technologies and strategies / minimizing impacts
- Restoring invaded habitats
- Assessing ecosystem impacts
- Assessing economic impacts
- Preventing introductions
- Conducting risk assessments
- Developing management plans
- Research initiatives
- Education and outreach
- Interagency coordination and cooperation

9.0 Related Research for the Gulf of Mexico Region

"These [invasive Asian] eels eat almost anything
– worms, shrimp, crayfish, other fishes, and frogs –
and they eat in massive quantities."

USGS Biologists, March 4, 2000 (Zaneski 2000)

Section 9.0 presents an inventory of recent peer-reviewed research activities relevant to selected Gulf-region aquatic invasive species, selected potential future aquatic invasive species for the Gulf region, and ballast water management. The purpose of this inventory is to (1) serve as an initial regional scientific directory on key current and emerging invasive species issues and (2) begin the processes of identifying regional research gaps and needs.

9.1 Inventory of Research Activities Relevant to the Gulf of Mexico Region

Literature searches on selected aquatic species (selected by the ISFT) and ballast water issues were conducted by searching several online databases of peer-reviewed literature, searching the Internet, and surveying representatives from the five Gulf States. Only relatively recent research activities were selected for the inventory, stressing the period from the early-1990s to present (including ongoing research). Where several references existed for a specific subject, one or more of those references were selected to represent the group. Hence, the effort yielded a representative, rather than a comprehensive, inventory of research literature.

An attempt was made to include only research activities relevant to the Gulf of Mexico region in the inventory. However, when searching for more general research on the aquatic invasive species issue and several aspects of ballast water management, for example treatment technologies, non-regional research activities were included in the inventory. Thus the inventory includes an international range of research on managing aquatic invasive species in general, and provides a more thorough list of ballast water management techniques.

Literature searches on 37 aquatic species were guided by 6 categories of specific keyword phrases, presented in Table 30. These categories and keywords represent slightly modified versions of those used by the Great Lakes Regional Panel and the National Sea Grant Program for classifying basic and applied research activities on aquatic invasive species (GLPANS 1997).

References, and abstracts when readily available, were added to the Research Inventory for each applicable research activity identified. Species-specific references selected for inclusion in the Research Inventory were organized by the six categories in Table 30 (note that categorizing references according to this scheme is inherently a somewhat subjective exercise). Individual references within each species/category section are organized by date, from most to least recent.

Table 30. Keyword Phrases for Literature Searches on Aquatic Species in the Gulf of Mexico Region

Category Number	Category Title	Keyword Phrases
1	Biology/life history	Life history; Reproductive biology; Population dynamics; Environmental requirements and tolerances; Parasites and diseases; Genetics; Physiology and behavior
2	Ecosystem effects	Community structure; Habitat (physical, chemical); Nutrient/contaminant cycles; Food web structure; Predator/prey interactions
3	Socioeconomic effects	Human health aspects; Recreation/tourism impacts; Shipping and navigation; Water use - agricultural, industrial, municipal; Policy and law determination; Resource management issues
4	Spread of established populations	Identification of potential invaders; Definition of vectors of introduction – shipping, bait, aquaria, canals, biological vectors; Determination of preventative measures; Establishment of international protocols
5	Control/mitigation of established populations	Habitat manipulation; Biological interactions – predator/prey, parasites/diseases; Physical measures; Chemical measures; Consequences of control; Integrated control strategy
6	Prevention of population establishment	Improvement in initial detection; Mechanisms of spread; Rate of spread; Range of spread; Natural barriers; Predictive models

This September 2000 version of the Research Inventory (Appendix I) contains over 400 individual references and is organized according to Table 31. Table 32 presents the distribution of references for each of the 37 species, by category, in the Research Inventory.

Table 31. Organization of the Research Inventory (Appendix I)

1.0 Vascular Plants

- 1.1 Eurasian watermilfoil (*Myriophyllum spicatum*)
- 1.2 Alligator weed (*Alternanthera philoxeroides*)
- 1.3 Water hyacinth (*Eichhornia crassipes*)
- 1.4 Hydrilla (*Hydrilla verticillata*)
- 1.5 Water lettuce (*Pistia stratiotes*)
- 1.6 Giant salvinia (*Salvinia molesta*)
- 1.7 Purple loosestrife (*Lythrum salicaria*)
- 1.8 Wetland nightshade (*Solanum tampicense*)

2.0 Semi-Aquatic Plants

- 2.1 Chinese tallow tree (*Sapium sebiferum*)
- 2.2 Torpedo grass (*Panicum repens*)
- 2.3 Carrotwood (*Cupaniopsis anacardioides*)
- 2.4 Brazilian pepper (*Schinus terebinthifolius*)
- 2.5 Melaleuca (*Melaleuca quinquenervia*)
- 2.6 Australian pine (*Casuarina equisetifolia*)

3.0 Mammals

- 3.1 Nutria (*Myocastor coypus*)

4.0 Fishes

- 4.1 Multiple-species documents
- 4.2 Grass carp (*Ctenopharyngodon idella*)
- 4.3 Spotted tilapia (*Tilapia mariae*)
- 4.4 Blue tilapia (*Oreochromis aureus*)
- 4.5 Blackchin tilapia (*Sarotherodon melanotheron* or *Tilapia melanotheron*)
- 4.6 Mayan cichlid (*Cichlasoma urophthalmus*)

5.0 Invertebrates

- 5.1 Multiple-species documents
- 5.2 Chinese mitten crab (*Eriocheir hepensis* or *Eriocheir sinensis*)
- 5.3 Exotic penaeid shrimps
- 5.4 Green crab (*Carcinus maenas*)
- 5.5 Veined rapa whelk (*Rapana venosa*)
- 5.6 Quagga mussel (*Dreissena bugensis*)
- 5.7 Green mussel (*Perna viridis*)
- 5.8 Brown mussel (*Perna perna* or *Perna indica*)
- 5.9 Zebra mussel (*Dreissena polymorpha*)
- 5.10 Asian clam (*Corbicula fluminea*)
- 5.11 A freshwater mussel (*Limnoperna fortunei*)
- 5.12 Portunid crab (*Charybdis hellerii*)

6.0 Amphibians

- 6.1 Cuban treefrog (*Osteopilus septentrionalis*)

7.0 Algae

- 7.1 Brown tide (*Aureoumbra lagunensis*)

8.0 Microbes

- 8.1 Multiple-species documents
- 8.2 Shrimp viruses
- 8.3 *Vibrio cholerae*
- 8.4 *Vibrio parahaemolyticus*
- 8.5 *Gymnodinium pulchellum*

9.0 Ballast Water

- 9.1 Ballast Water Research Summaries
- 9.2 Ballast Water Treatment Research
- 9.3 Ballast Water Sampling Research
- 9.4 Ballast Water Risk Assessment Research
- 9.5 Ballast Water Exchange Research

10.0 General – Nonindigenous Aquatic Species

- 10.1 Nonindigenous Aquatic Species Research Summaries
- 10.2 General Documents

11.0 Nonindigenous Aquatic Species Online Databases and Clearinghouses

Table 32. Distribution of References, by Research Category, for Each Species in the Research Inventory

Species Group	Species	No. of References Per Research Category*					
		1-Biology	2-Eco Eff	3-Socio	4-Spread	5-Control	6-Prevent
Vascular Plants	Eurasian watermilfoil	4	9	--	4	11	--
	Alligator weed	--	--	--	--	1	--
	Water hyacinth	1	2	--	--	3	--
	Hydrilla	8	3	1	--	11	--
	Water lettuce	2	2	--	--	5	--
	Giant salvinia	1	--	--	--	--	--
	Purple loosestrife	3	3	--	--	1	--
	Wetland nightshade	--	1	--	--	--	--
Semi-Aquatic Plants	Chinese tallow tree	1	2	--	1	--	--
	Torpedo grass	--	--	--	--	5	--
	Carrotwood	--	--	--	1	--	--
	Brazilian pepper **	--	1	--	--	2	--
	Melaleuca **	4	1	--	3	13	--
	Australian pine	--	1	--	--	1	--
Mammals	Nutria	2	12	--	--	1	--
Fishes	Multiple-species docs	Total of 10					
	Grass carp	3	4	--	3	2	--
	Spotted tilapia	2	--	--	--	--	--
	Blue tilapia	6	--	--	--	--	--
	Blackchin tilapia	4	--	--	--	--	--
	Mayan cichlid	1	--	--	--	--	--
Invertebrates	Multiple-species docs	Total of 3					
	Chinese mitten crab **	2	--	--	--	--	--
	Exotic penaeid shrimps	1	--	--	--	--	--
	Green crab	--	2	--	1	--	--
	Veined rapa whelk	1	--	--	--	--	--
	Quagga mussel	8	--	--	1	1	--
	Green mussel	2	--	--	--	--	--
	Brown mussel	3	1	--	7	--	--
	Zebra mussel	24	5	3	9	8	--
	Asian clam	4	1	--	--	3	--
	Freshwater mussel	1	--	--	1	--	--
	Portunid crab	1	--	--	--	--	--
Amphibians	Cuban treefrog	1	--	--	--	--	--
Algae	Brown tide	9	10	--	--	--	--
Microbes	Multiple-species docs	Total of 3					
	Shrimp viruses **	4	1	2	2	4	3
	<i>Vibrio cholerae</i>	2	--	--	4	--	--
	<i>Vibrio parahaemolyticus</i>	2	--	--	--	--	--
	<i>Gymnodinium pulchellum</i>	--	1	--	--	--	--
Ballast Water	Research Summaries	Total of 4					
	Treatment Research	Total of 17					
	Sampling Research	Total of 3					
	Risk Assessment Research	Total of 17					
	Exchange Research	Total of 2					
NAS General	Research Summaries	Total of 3					
	General Documents **	--	4	6	12	10	7
	Online Databases	Total of 9					

* See Table 30 for a description of these categories. ** In addition, one or more species summary references.

9.2 Invasive Species Research Needs for the Gulf of Mexico Region

This section describes the status of three efforts, all undertaken by various committees of the GMP, to compile and prioritize research needs related to invasive species (terrestrial and aquatic). It is expected that the ongoing GMP Experts Panel for Invasive Species Research will consider work from previous efforts, and produce a more definitive list of research needs. It is also expected that the Experts Panel will solicit comments on the initial draft(s) of their research needs list from related GMP committees and other appropriate stakeholders.

GMP Experts Panel for Invasive Species Research

The GMP is currently sponsoring meetings of an ad-hoc Experts Panel for Invasive Species Research. The Panel Co-Chairs are Dr. Herb Kumpf, National Marine Fisheries Service, and Dr. Karen Steidinger, Florida Marine Research Institute. It is expected that the Expert Panel will complete a thorough invasive species research guidance / research needs report in 2001. Any future versions of this report will include the Panel's findings.

Research Subcommittee of GMP Monitoring, Modeling, and Research Committee

In March 2000, the Research Subcommittee of the GMP Monitoring, Modeling, and Research Committee, assisted by the Invasive Species Focus Team Co-Chairs, defined the Priority Research Questions for the GMP's invasive species focus area. These Priority Research Questions were further refined by the ISFT in June 2000 for this report.

1. What methods, data, or models are required to assess the potential human health and/or ecological risks associated with nonindigenous species introductions?
 - a. What predictive associations/models are required to assess species and source locations that pose a high risk to Gulf waters?
 - b. What laboratory and field methods, data, and models are required to assess both human health and ecological risks associated with introductions of nonindigenous species?
2. What is the ecological and economic extent and effects of invasive species in the Gulf of Mexico?
 - a. What nonindigenous species are present in the Gulf of Mexico and what are their economic, human health, and ecological effects?
 - b. What methods, models, and data are required to detect and track subsequent invasions and spread of nonindigenous species in Gulf watersheds and Gulf-wide?
3. What non-invasive species are transported to and released into Gulf ports from ship ballast?
 - a. What methods are needed to monitor compliance of ballast exchange in the Gulf of Mexico?
 - b. What are the characteristics of biological (taxa and quantity) contamination of ballast discharges into major Gulf ports?
 - c. What is the anticipated 10-year shipping forecast for Gulf ports?

- d. What methods are needed to detect unknown species in ballast water released into the Gulf of Mexico, or to monitor for worst case scenarios like human pathogens and/or plant pathogens?
 - e. What are the ecological vulnerabilities, associated with nonindigenous species, of particular Gulf areas subject to shipping pressures?
4. What are the ecological risks associated with the introduction of nonindigenous viruses into Gulf waters from aquaculture and seafood processing? At the same time, what are the risks associated with viruses that enter aquaculture facilities from a variety of sources, including stocked shrimp, processing wastes carried into ponds by birds, etc.
 - a. What simple biological/chemical indicators are required to determine the presence/absence of shrimp viruses in environmental samples?
 - b. What biological indicators are required to routinely monitoring for the presence of viruses in wild populations of commercially important species?
 - c. What are the chemical and biological characteristics of effluent from aquaculture and seafood processing plants that might affect the Gulf of Mexico, or other areas receiving aquaculture products?
 5. What technologies might prevent and/or control invasive species introductions?
 - a. What techniques are effective in the shipboard treatment of ballast water?
 - b. What are the best management/treatment practices to identify and control the release of shrimp viruses and other microorganisms from aquaculture and seafood processing plants, or to other areas receiving aquaculture products?

Invasive Species Focus Team

The following specific research needs were defined by the ISFT Co-Chairs, and refined by the ISFT in June 2000. They are organized by generic topic areas, and listed without regard to priority.

Risk Analysis

- Determine what methods, data, or models are required to assess the risk of trade pathways and trade partner sources associated with invasive species introductions.

Prevention of New Introductions

- Determine preventive strategies and develop model control mechanisms.
- Develop risk assessments for potential and initial presence of nonindigenous aquatic species.
- Inventory Gulf of Mexico marine waters for nonindigenous and invasive species.

Reducing the Spread of Established Populations

- Develop basin specific and Gulfwide quantitative databases to pinpoint and track invasions and spread of aquatic invasive species.

- Conduct a Gulfwide status and trends analysis on invasive species (aquatic and terrestrial) to include, but not limited to, species, geographic distribution, habitat types(s) invaded, impacts, rate of spread, modes of spread, environmental requirements, etc.
- Develop monitoring protocols that can be incorporated into existing water quality monitoring to identify presence of unknown species or changes in ecology that might be attributed to an introduction. Data would be made available for local follow-up or agency follow-up, as appropriate.
- Inventory Gulf of Mexico marine waters for nonindigenous and invasive species.

Ballast Water: Management and Treatment

- Determine what methods, data, or models are required to assess the risk of ballast water pathways and trade partner sources associated with nonindigenous species introductions.
- Develop mechanisms to ensure that open ocean exchanges have been performed (a USCG research project).
- Develop mechanisms to regulate ballast water discharge.
- Refine methods/procedures for monitoring compliance of ballast exchange in the Gulf of Mexico.
- Characterize biological contents (taxa, levels) of ballast discharges in major ports.
- Establish a long-term database (10+ years) of shipping activities of Gulf Ports.
- Determine the effectiveness of ballast water exchange (90 percent for commercial vessels and 2 times for military vessels) in achieving percent kill or removal of organisms in the ballast water column and sediments.
- Determine the effectiveness of ballast water exchange (90 percent for commercial vessels and 2 times for military vessels) in preventing the establishment of reproducing, self-sustaining populations of nonindigenous aquatic organisms. The research question here is what critical population densities are needed for a successful invasion (establishment).
- Determine the effectiveness of alternate compliance technologies (ballast water treatments) in achieving percent kill or removal of ballast organisms and in the prevention of established populations of nonindigenous aquatic species.

Ballast Water: Ecosystem Effects

- Determine what methods, data, or models are required to assess the risk of ballast water pathways and trade partner sources associated with nonindigenous species introductions.
- Determine the ecosystem vulnerability to aquatic invasive species of the major Gulf ports and adjacent inland waters. This might be done by comparing environmental parameters of Gulf ports with those of the primary foreign ports of origin (ports where ballast is collected) for the majority of shipping at each Gulf port destination.
- Determine similar vulnerabilities for aquaculture and water garden imports, handling, marketing, etc. through the Gulf region.

Shrimp Viruses

- Develop and test Best Management Practices (BMP) for identification and control of shrimp viruses during the delivery of seafood.
- Develop simple probe(s) for determining the presence/absence of shrimp viruses.
- Establish a monitoring program/protocol to test for the presence of virus in wild shrimp populations.

10.0 Recommended Report Enhancements

"Nonindigenous aquatic organisms continue to spread into new ecosystems throughout North America."

(Claudi and Leach 2000)

This version of *An Initial Survey of Aquatic Invasive Species Issues in the Gulf of Mexico Region* attempts to initially describe the occurrence, management, and impacts of aquatic invasive species in the Gulf of Mexico region. The ISFT intends to periodically update this report with current information and eventually expand the scope of the document to include invasive terrestrial species in the Gulf of Mexico region. With future versions of the document in mind, the ISFT maintained a list of recommended report enhancements throughout the report review process. Recommendations are organized by sections of the current document.

Overall / Additions

- Expand the scope of the document to include invasive terrestrial species in the Gulf of Mexico region.
- Include the results of a rigorous study of the economic impacts of invasive species in the Gulf region.
- Add a major section to the document that discusses what future actions each Gulf State would like to undertake relevant to aquatic invasive species. This would help readers understand future Gulfwide management priorities and provide a list of initiatives that might require outside funding.
- Transfer inventories developed for this report (e.g., *Inventory of Nonindigenous Aquatic Species Occurring in the Gulf of Mexico Region*) from a word processor format to a database format, and then make these databases available on the Internet.

4.0 Aquatic Invasive Species Management Priorities in the Five Gulf States

- For Sections 4.1 through 4.5, which list current and potential future aquatic invasive species management priorities for each Gulf State, conduct intensive interviews with state and federal agencies, local organizations, university researchers, and industry representatives to get a better, consensus-generated list of what species and issues are priorities. Interviews should request, at minimum, the following information for each species: common name; scientific name; place of origin; confirmed or suspected introduction pathway; biological and/or economic rationale for concern (potential impacts); impacts experienced; management status; and control/prevention strategies. [suggested by the ISFT, June 20-21, 2000]

- Include results of a rigorous risk assessment of active invasive species pathways to the Gulf region (on a state-by-state or regional basis), and rank them for management focus.

6.0 Gulfwide Issues Addressed by the ISFT: Ballast Water

- For Section 6.3, which discusses the management framework for ballast water, contact port authorities in the Gulf of Mexico region about ballast water management initiatives planned or underway at the port level. [suggested by Marilyn Barrett-O’Leary]

7.0 The Management Framework for Addressing Invasive Species in the Gulf of Mexico Region

- Describe the management framework within each of the Gulf-region’s seven National Estuary Programs related to invasive species (e.g., CCMP Action Plans). [Suggested by Bill Holland]
- Describe the management framework within each of the Gulf-region’s four National Estuarine Research Reserves related to invasive species. [Suggested by Richard Wallace]

9.0 Related Research for the Gulf of Mexico Region

- The GMP is currently sponsoring meetings of an ad-hoc Experts Panel for Invasive Species Research. The Panel Co-Chairs are Dr. Herb Kumpf, National Marine Fisheries Service, and Dr. Karen Steidinger, Florida Marine Research Institute. It is expected that the Panel will complete a thorough invasive species research guidance / research needs report in 2001. Any future versions of this report will include the Expert Panel’s findings.
- In this version of the report, the Research Inventory was developed by (1) searching several online databases of peer-reviewed journal articles, (2) searching the Internet for gray literature sources, and (3) asking a few state and local officials about gray literature sources. A mail or e-mail survey should be prepared and extensively distributed to the research community to augment the contents of the Research Inventory. This will ensure that the Research Inventory includes more ongoing research. In addition, the species represented in the Research Inventory should be expanded as needed by the Gulf States.

Appendix B: Inventory of Nonindigenous Species Occurring in the Gulf of Mexico Region

- Widely distribute the initial inventory to state agencies, local organizations, and university researchers to verify records and augment the inventory. Require and document source references for any changes or additions to the inventory. [suggested by the ISFT, June 20-21, 2000]
- Improve the “reported/established” status column by differentiating whether the species identification was (1) single specimens or small numbers of scattered individuals that do not represent populations; (2) small, isolated populations that are unlikely to spread due to environmental constraints or barriers; or (3) established populations with no apparent barriers to expansion (Hill 2001).

- Create a column in the matrix that identifies the place of origin – country, state, region, area – for the species in question. [suggested by Paul Carangelo]
- Create a column in the matrix that identifies the pathway(s) of introduction for the species in question. [suggested by Paul Carangelo]
- Create one or more columns in the matrix that identify which species occur in the Gulf of Mexico Program's 12 Priority Coastal Watershed Areas. [suggested by Bill Holland]

11.0 Glossary

Aquatic Species

All plants, animals, and microbes that are obligated to live in a freshwater, estuarine (*i.e.*, tidally-influenced), or marine waterbody (including a freshwater or coastal wetland) during all or part of their lives (adapted from Benson 2000).

Cryptogenic Species

A species whose status as indigenous or nonindigenous is not resolved (Carlton and Ruckelshaus 1997).

Ecosystem

A community of organisms and their physical environment that interact as an ecological unit (McCann 1996).

Established Species

A species with one or more successfully reproducing or breeding (*i.e.*, permanent) populations in an open ecosystem (*i.e.*, outside of human control and confinement), which are unlikely to be eliminated by man or natural causes. Naturalized is a synonym for established.

Exotic Species

A species that is not indigenous to the geographic area under discussion, for the purposes of this report, the U.S. (OTA 1993, Fuller et al. 1999). Alien and foreign are synonyms for exotic.

Extirpated

Where a species is completely removed from an open ecosystem, either as a result of natural causes or eradication by humans (adapted from Fuller et al. 1999).

Gulf of Mexico Region

The Gulf of Mexico region includes the area within the political boundaries of the five Gulf States – Florida, Alabama, Mississippi, Louisiana, and Texas – and waters of the Gulf of Mexico to the seaward boundary of the U.S. Exclusive Economic Zone.

Indigenous Species

A species occurring naturally in an area or ecosystem; a species that is a member of the natural community (Fuller et al. 1999). Native is a synonym for indigenous.

Introduction

The act of an organism being moved by either intentional and unintentional human-facilitated transference, including escape from confinement, to an area beyond its natural range or natural zone of potential dispersal. This definition does not include organisms imported and cultured in human control and confinement (e.g., aquaculture or research facility, ornamental pond), unless it escapes.

Invasive Species

A species that threatens the diversity or abundance of native species; the ecological stability of impacted ecosystems; economic activities (e.g., agricultural, aquacultural, commercial, or recreational) dependent on these ecosystems; and human health. Synonyms for invasive species include harmful species, injurious species, invader, noxious species, nuisance species, pest, and weed.

Nonindigenous Species

Any individual, group, or population of a species, or other viable biological material, that is intentionally or unintentionally moved by human activities, beyond its natural range or natural zone of potential dispersal, including moves from one continent or country into another and moves within a country or region; includes all domesticated and feral species, and all hybrids except for naturally occurring crosses between indigenous species. Introduced and non-native are synonyms for nonindigenous.

Note that the Florida Department of Agriculture and Consumer Services *does not support* a definition of nonindigenous species that includes pathogens, as pathogens are in the regulatory province of the U.S. Food and Drug Administration (human) and U.S. Department of Agriculture (agriculture) (Zajicek, pers. comm.).

Pathway

The means by which a species enters an open ecosystem (adapted from McCann 1996). Vector is a synonym for pathway.

Taxon

A group of organisms of any taxonomic rank. The plural of taxon is taxa (Fuller et al. 1999).

Transplanted Species

A species native to the geographic area under discussion (for the purposes of this report the U.S.) that is intentionally or unintentionally released by humans, including escaping from confinement, into an area beyond its natural range, or natural zone of potential dispersal, within that country (adapted from Fuller et al. 1999).

Waterbody

Any ocean, sea, gulf, bay, lake, river, stream, bayou, wetland, or spring, or any reservoir, pond, canal, or drainage ditch considered to be outside the boundaries or control of captive conditions (e.g., aquaculture facility, research facility, fish farm, etc.). A waterbody may have a permanent, temporary, or intermittent water connection (e.g., via flooding) with other waterbodies (adapted from Fuller et al 1999).

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Steve Heath, Marine Resources Division, Alabama Department of Conservation and Natural Resources, June 11, 2001.

Rhandy Helton, Aquatic Vegetative Control Group, Texas Parks and Wildlife Department, February 8, 2001.

Bill Holland, Invasive Species Focus Team Co-Chair, Gulf of Mexico Program, Stennis Space Center, Mississippi, May to September 2000.

Ken Johnson, Texas Veterinarian Medical Diagnostic Center, Texas A&M University, December 14, 2000.

Herb Kumpf, National Marine Fisheries Service, Panama City, Florida, October 2000.

Susan McCarthy, Research Microbiologist, Gulf Coast Seafood Laboratory, U.S. Food and Drug Administration, Dauphin Island, Alabama, July 17, 2000.

Tom McIlwain, National Marine Fisheries Service, Pascagoula, Mississippi, August 31, 2000.

Whitman Miller, Smithsonian Environmental Research Center, Edgewater, Maryland, August 31, 2000.

Vernon Minton, Division of Marine Resources, Alabama Department of Conservation and Natural Resources, February 1, 2001.

Dan Moulton, Coastal Conservation Branch, Texas Parks and Wildlife Department, Austin, Texas, November 11, 2000.

Dan Roberts, Florida Marine Research Institute, Florida Fish and Wildlife Conservation Commission, St. Petersburg, Florida, August 2000.

Jeff Schardt, Bureau of Invasive Plant Management, Florida Department of Environmental Protection, Tallahassee, Florida, August 4, 2000.

Carol Shieh, Gulf Coast Seafood Laboratory, U.S. Food and Drug Administration, Dauphin Island, Alabama, July 11, 2000.

Todd Slack, State Ichthyologist, Mississippi Museum of Natural Science, Department of Fisheries, Wildlife, and Parks, Jackson, Mississippi, July 27, 2000.

Granvil Treece, Texas Sea Grant Program, Bryan, Texas, November 21, 2000.

Wes Tunnell, Texas A&M University – Corpus Christi, Corpus Christi, Texas, personal communication reported in Stickney 2001.

Tom Van Devender, Mississippi Department of Marine Resources, February 2, 2001.

Richard Wallace, Director, Auburn University Marine Extension and Research Center, Mobile, Alabama, August 2, 2000.

Paul Zajicek, Division of Aquaculture, Florida Department of Agriculture and Consumer Services, Tallahassee, Florida, August 8, 2000.

Joe Zolcynski, Division of Wildlife and Freshwater Fisheries, Alabama Department of Conservation and Natural Resources, February 1, 2001.